# ENVIRONMENTAL ASSESSMENT

## PROPOSED NAVIGATION IMPROVEMENT PROJECT LYNN HARBOR, MASSACHUSETTS

New England Division
U.S. Army Corps of Engineers
424 Trapelo Road
Waltham, MA 02254

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# LYNN HARBOR ENVIRONMENTAL REPORT
## EXECUTIVE SUMMARY

As part of a plan to encourage the economic revitalization of the City of Lynn, the U.S. Army Corps of Engineers, New England Division, has been asked for a feasibility study to dredge channels in Lynn Harbor and to build a breakwater. Nine alternative plans have been recommended. The alternatives are presented in Table 1 and their associated costs and benefits, in Table 2.

Table 1

DESCRIPTION OF ALTERNATIVES

| Alternative | Description |
|---|---|
| 1 | No action - Maintain only the existing authorized channel |
| 2 | Fully develop navigational channels, to include the municipal channel and a turning basin |
| 3 | Construct a breakwater with Alternative 2 |
| 4 | Circular access utilizing the partially dredged gas company channel |
| 5 | Alternative 4 with a breakwater |
| 6 | Same as 3 but with mooring areas dredged for recreational craft |
| 7 | Same as 5 but with mooring areas dredged for recreational craft |
| 8 | Dredge whole harbor and extend breakwater for recreational development |
| 9 | Deep draft dredging |

Wave studies indicated that a breakwater would not be necessary. Construction of a breakwater would also be likely to cause erosion at the Point of Pines.

Analysis of the affected biologic communities showed that they are likely to quickly recolonize the disturbed bottom. Modified versions of Alternatives 6, 7, and 8, involving dredging but no breakwater were considered.

Disposal of dredged material was also analyzed, with the following alternatives evaluated:

1. Upland Disposal
2. Beach Nourishment at Revere Beach
3. Use as Fill at Lynn and South Boston Naval Annex
4. Ocean Disposal at the Boston Foul Area

Table 2

ALTERNATIVES, COSTS, AND BENEFITS

| Alternative | Environmental Cost | First Cost ($\$ \times 10^6$) | Annual Cost ($\$ \times 10^6$) | Annual Benefit ($\$ \times 10^6$) |
|---|---|---|---|---|
| 1 | Dredge 0 $yd^3$ | 0 | 0 | 0 |
| 2 | Dredge 835,000 $yd^3$ | 3.08 | 0.22 | 1.53 |
| 3 | Dredge 835,000 $yd^3$ | 6.63 | 0.47 | 6.10 |
| 4 | Dredge 1,296,700 $yd^3$ | 5.42 | 0.39 | 1.53 |
| 5 | Dredge 1,296,700 $yd^3$ | 8.90 | 0.64 | 6.10 |
| 6 | Dredge 1,387,042 $yd^3$ | 6.96 | 0.50 | 6.42 |
| 7 | Dredge 1,387,042 $yd^3$ | 9.29 | 0.66 | 6.42 |
| 8 | Dredge 3,206,000 $yd^3$ | 21.96 | 1.57 | 6.55 |
| 9 | Dredge 8,000,000 $yd^3$ | 30.62 | 2.18 | Not Calculated |

Upland disposal was considered but subsequently rejected because of the anticipated volume of the dredged material. However, there is a need for material for the replenishment of nearby Revere Beach. This would be the environmentally preferred alternative because of the ability of beach communities to adapt to sudden environmental changes. However, the dredged material must meet certain criteria and will require analysis. A small amount of fill is required at Lynn in connection with the Lynn Heritage Park project, and a larger amount of fill is required for Massport's Containerport project at Boston Marine Industrial Park. It is probable that the material from Lynn Harbor will meet the water quality criteria for use as fill on either of these projects.

Ocean disposal at the Boston Foul area is also a viable alternative. It is probable that the dredged material will meet criteria for disposal at this site, as well. Bioassays and bioaccumulation studies conducted by the State and the Corps on samples from the Federal channel and the Municipal Channel suggest that the material is not harmful to marine life.

Since it is probable that a large portion of the dredged material will not meet the grain size criteria for beach replenishment, it is recommended that the material be used for fill at the Boston Marine Industrial Park. If at that time Massport no longer requires the fill, then ocean disposal at the Boston Foul area is recommended.

# 1.0 PURPOSE AND NEED FOR PROPOSED ACTION

The Lynn Economic Development and Industrial Corporation (LEDIC) and the America East Corporation Inc. have collaborated on plans to revitalize the commercial and recreational use of Lynn's existing waterfront by the construction of Lynn Marine Industrial Park.

The U.S. Army Corps of Engineers was requested to dredge the municipal channel to a depth of -25 ft Mean Low Water (MLW); to dredge a mooring basin to the same depth; and to construct a breakwater. Figure 1 presents a map of the area of the proposed project. The local request for Federal action required construction of a breakwater to protect the Harbor, in addition to the full development of channels under existing authorization. Thus, wave studies at the site were implemented to determine whether there was a need for the breakwater.

The project has as its major objectives the achievement of the following goals:

1. To strengthen and expand the decreasing tax base of the City of Lynn

2. To assist in the stabilization of the regional economic base

3. To provide the necessary expansion facilities for the fishing industry of Massachusetts

4. To provide jobs for unemployed workers of this region

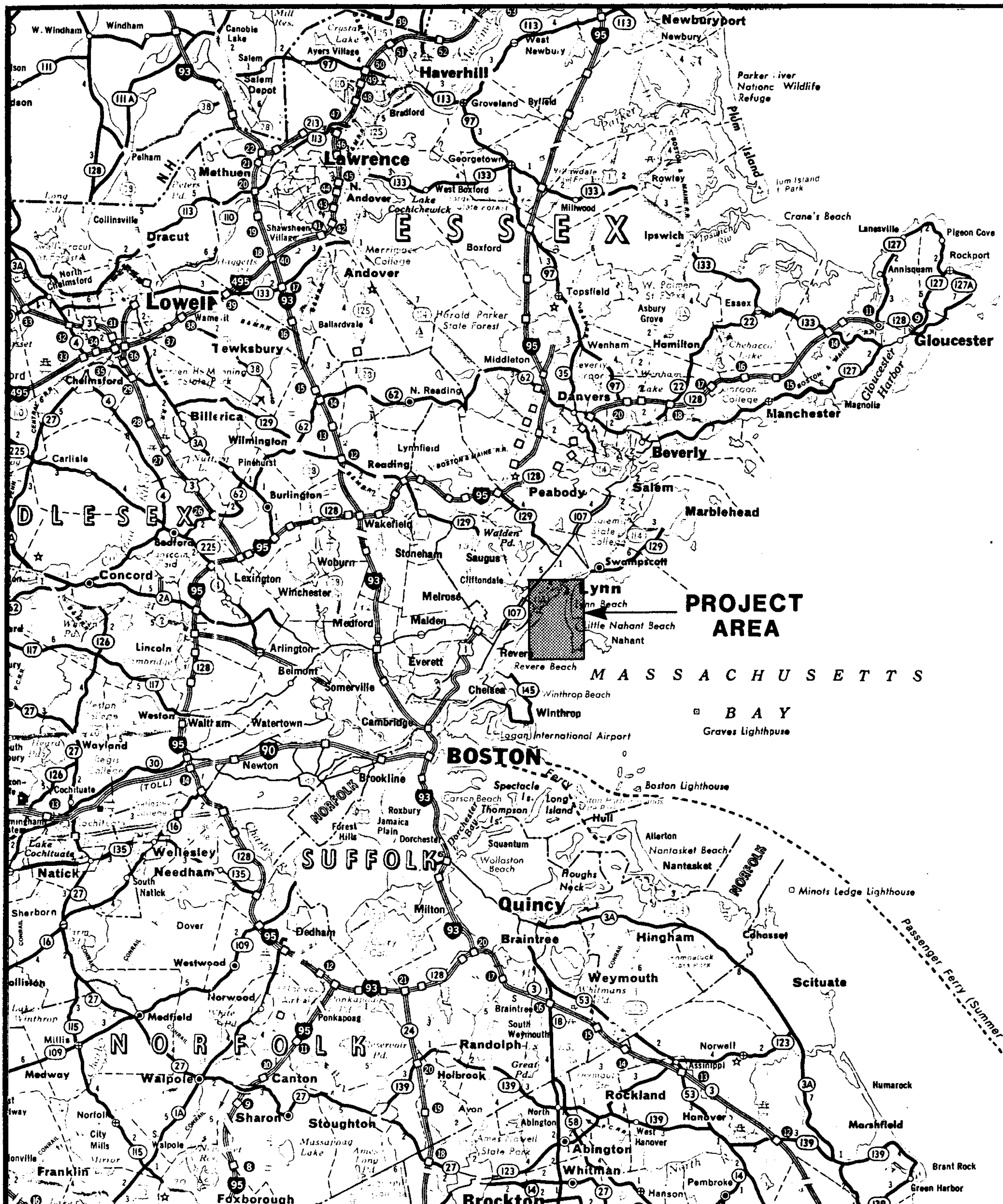
5. To develop Lynn's coastline in a manner consistent with recently published policies for coastal development

6. To re-establish Lynn as a focal point of economic activity north of Boston

## 1.1 Project Design Requirements

The development of the Lynn Marine Industrial Park requires certain basic infrastructure improvements primarily related to the marine environment. Improvements are required in the Federal Channel and Municipal Channel to permit larger offshore fishing vessels and smaller ocean-going vessels to transit the Harbor and reach the proposed municipal wharf areas. A turning basin must also be provided to allow the larger vessels adequate depth of water to turn to exit the ship channel.

A depth of -25 ft at MLW was established as the depth of channel to accommodate the draft requirements of the refrigerator and general cargo vessels expected to call at the Port of Lynn. This depth of channel will also be adequate for the larger offshore fishing trawlers expected to have a draft of approximately 17 to 18 ft fully laden (Lynn Economic Development and Industrial Corporation, 1979).




C.O.E. SMALL NAVIGATION PROJECT
Lynn Harbor, Massachusetts

PROJECT LOCATION MAP

FIGURE 1

# 2.0 ALTERNATIVES

Nine alternatives have been evaluated in conjunction with the request for dredging and construction of a breakwater. In addition, alternative dredged material disposal sites have been investigated and evaluated both in financial and environmental terms.

## 2.1 Harbor Alternatives

The alternative configurations and combinations which have been evaluated include:

1. No-Action - This alternative continues the maintenance only of the existing authorized channel.

2. Fully develop navigation channels to include the municipal channel and a turning basin for full municipal waterfront access.

3. Construct a breakwater to protect the Harbor with fully developed channels.

4. Circular access utilizing the partially dredged gas company channel without a breakwater.

5. Circular access utilizing the gas company channel and a breakwater.

6. Same as No. 3 but with mooring areas dredged for recreational craft.

7. Same as No. 5 but with mooring areas dredged for recreational craft.

8. Dredge whole Harbor and extend breakwater for recreation development.

9. Deep draft dredging and breakwater construction.

### Effects to the Environment

Building a breakwater will lessen wave heights in the Harbor by approximately 80 to 90 percent. A new channel is likely to be produced by erosion at the tip of the breakwater. The breakwater could impact water quality in the area enclosed by the breakwater and the Harbor's northern shore. The result of the breakwater would be to constrict the channel and thus reduce the tidal exchange from 60 to 30 percent. This will result in cumulative concentration of contaminants within the Harbor. Here, modeling studies have shown that very little exchange of water occurs either on ebb or flood tides (JMCA, 1980). Additionally, breakwater construction is likely to cause erosion at Point of Pines.

## 2.2 Alternative 1 - No-Action and Its Effects

The No-Action Alternative allows the existing channel to remain at a depth of 22 ft. No basin would be dredged; no breakwater would be constructed; and no further channel dredging would take place (Figure 2).

### 2.2.1 Economic Impact of No-Action

The increase in long term employment as well as the short term construction employment opportunities anticipated as a result of this project would be eliminated, if the No-Action alternative were selected.

### 2.2.2 Alternative 2

Alternative 2 involves fully developing navigational channels to include the municipal channel and turning basin for full municipal waterfront access. Existing channels will be deepened from the existing -22 ft MLW to -25 ft MLW (Figure 3).

#### 2.2.2.1 Economic Impact of Alternatives 2

The proposed action will result in an increase in long term local employment for approximately 887 to 937 persons and add 7.3 to 7.5 million dollars in income (LEDIC, 1979). The short term economic impacts of construction are equivalent to 1,000 man years.

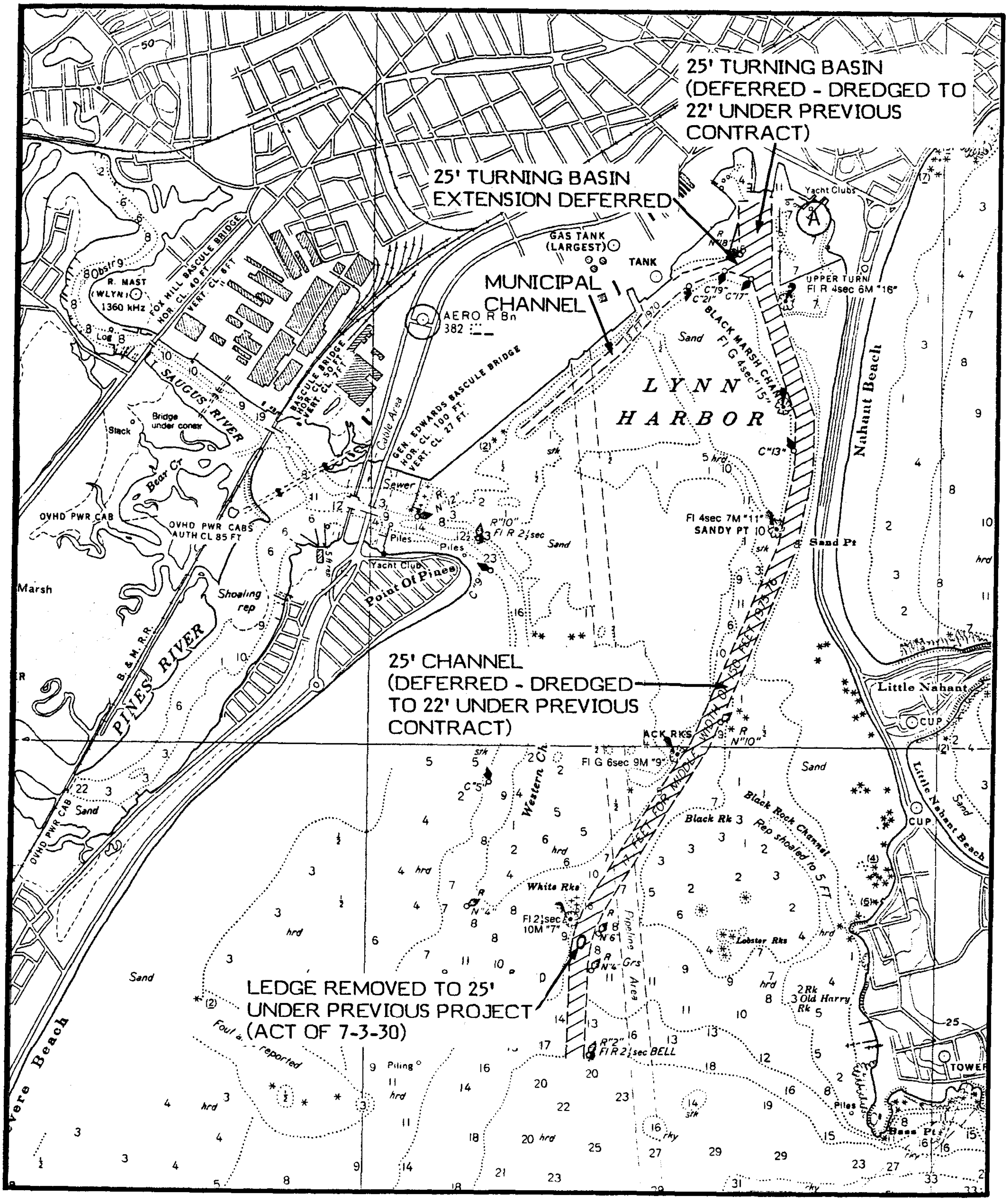
Alternative 2 will cost $3,088,700. An annual cost (based on a 50 year economic life) was calculated using a capital recovery factor based on a 6-5/8 percent interest rate and adding annual maintenance costs. This annual cost was calculated at $220,250.00.

### 2.2.3 Alternative 3

Alternative 3 is the same as Alternative 2 with the addition of a breakwater. New data on wave heights in Lynn Harbor (JMCA, 1980) show that maximum wave heights within the Harbor during hurricane force winds will be less than 3 ft. This obviates the need for a breakwater.

#### 2.2.3.1 Economic Impact of Alternative 3

LEDIC's (1979) plan to develop Lynn Harbor assumed that a breakwater would be necessary to attract commercial vessels to the Harbor. This evaluation was based on insufficient data on wave heights. The breakwater has since been shown to be unnecessary (JMCA, 1980). The additional cost of breakwater construction will be $3,538,700.00. The annual cost, based on a fifty year economic life, due to the breakwater alone, will be $252,350.00.

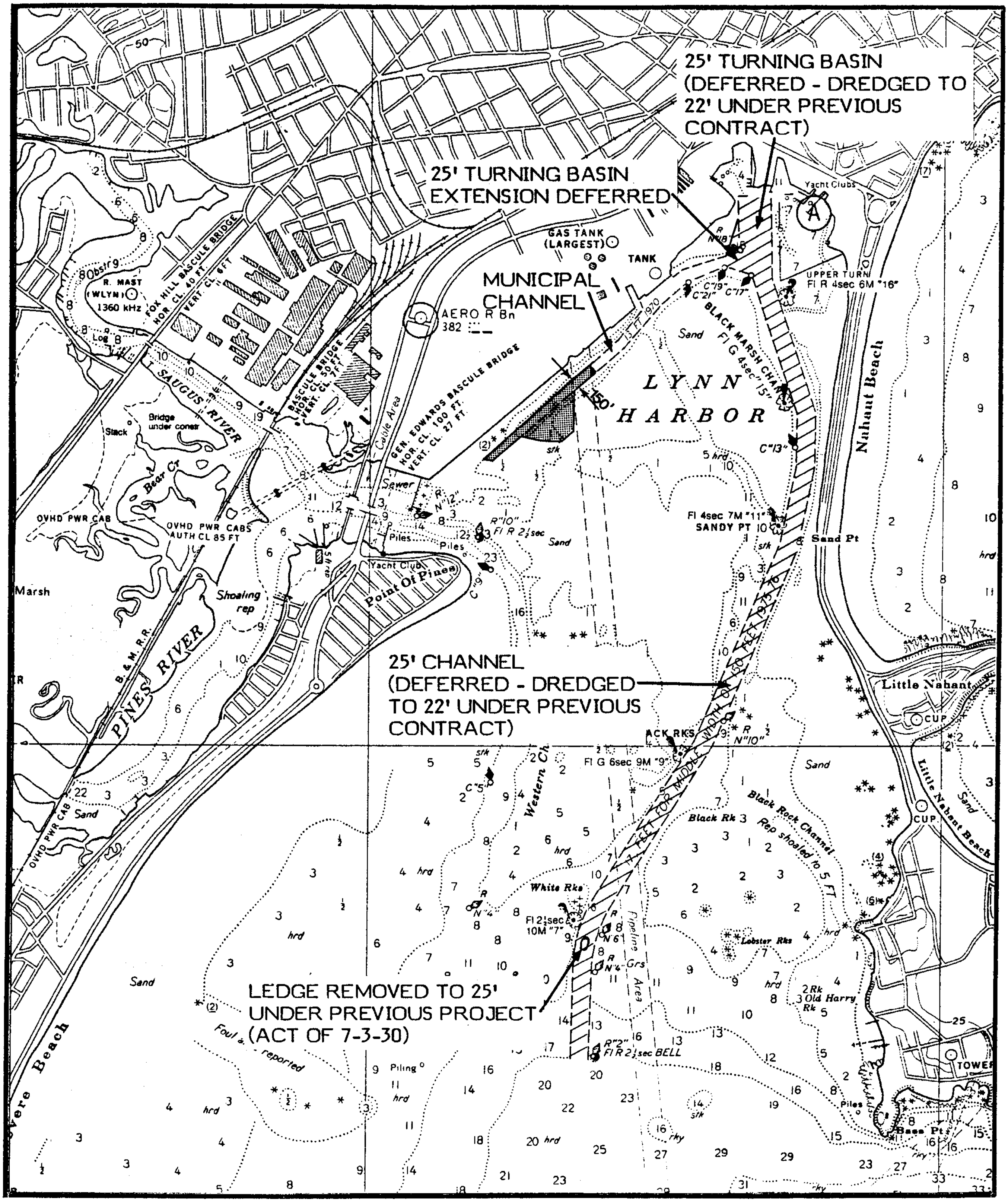



C.O.E. SMALL NAVIGATION PROJECT
Lynn Harbor, Massachusetts
SOURCE: U.S.ACOE 1979

NO ACTION

Scale 1:25,000

FIGURE 2




C.O.E. SMALL NAVIGATION PROJECT
Lynn Harbor, Massachusetts
SOURCE: U.S.ACOE 1979

Scale 1:25,000

ALTERNATIVE 2

Corps Dredging

FIGURE 3

The environmental cost of the breakwater will involve increased erosion of Point of Pines and loss of habitat at the site of the breakwater.

### 2.2.4 Alternatives 4

Alternative 4 involves dredging a circular access route which would utilize the partially dredged gas company channel without a breakwater. All channels would be dredged to a depth of -25 ft MLW (Figure 4).

#### 2.2.4.1 Economic Impact of Alternative 4

Benefits accruing from Alternative 4 were assumed to be equal to those accruing from Alternative 2 (U.S. ACOE, 1979). The cost for Alternative 4 is estimated as $5,419,720.00 with an annual cost of $386,480.00 (U.S. ACOE, 1979).

### 2.2.5 Alternative 5

Alternative 5 is the same as Alternative 4 with the addition of the breakwater.

#### 2.2.5.1 Economic Impact of Alternatives

The impacts, both environmental and economic, of Alternative 5 will be the same as for Alternative 4 with the additional impacts due to breakwater construction (see 2.2.3.1).

### 2.2.6 Alternative 6

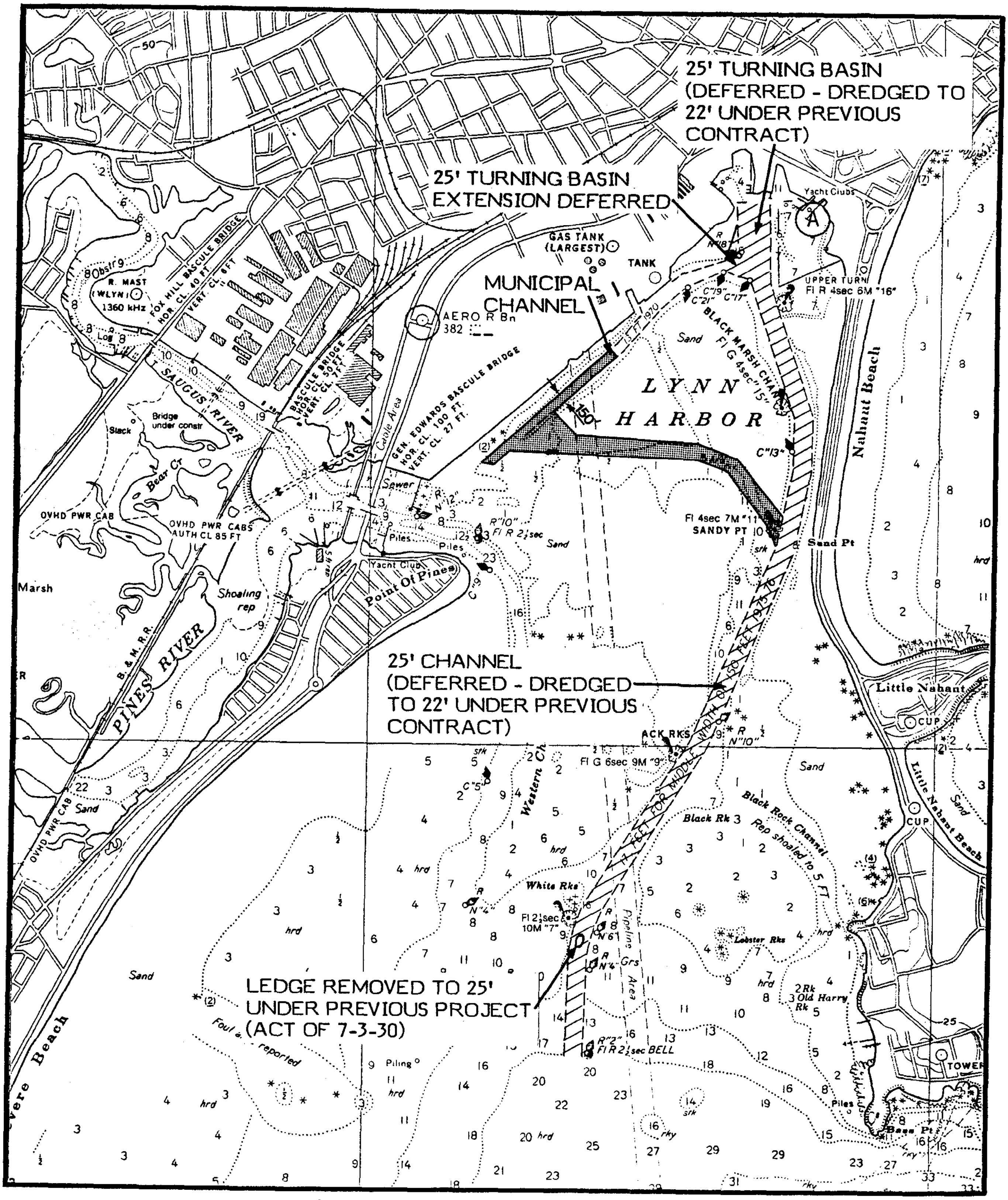
This alternative involves the same work as Alternative 3 with an additional seven acres of dredging to provide moorage for recreational craft (Figure 5).

#### 2.2.6.1 Economic Impact of Alternative 6

Net income benefits for Alternative 6 would be the same as those for Alternatives 2 and 3. The U.S. ACOE (1979) estimates that benefits due to additional recreation would equal $311,875.00. The recreational benefit is calculated using the net return on investment for each craft utilized on a for-hire basis. The estimated cost for Alternative 4 would be $6,961,550.00 or $496,400.00 annually.

### 2.2.7 Alternative 7

Alternative 7 is equivalent to Alternative 5 with the additional dredging of the seven acre recreational moorage (Figure 6).



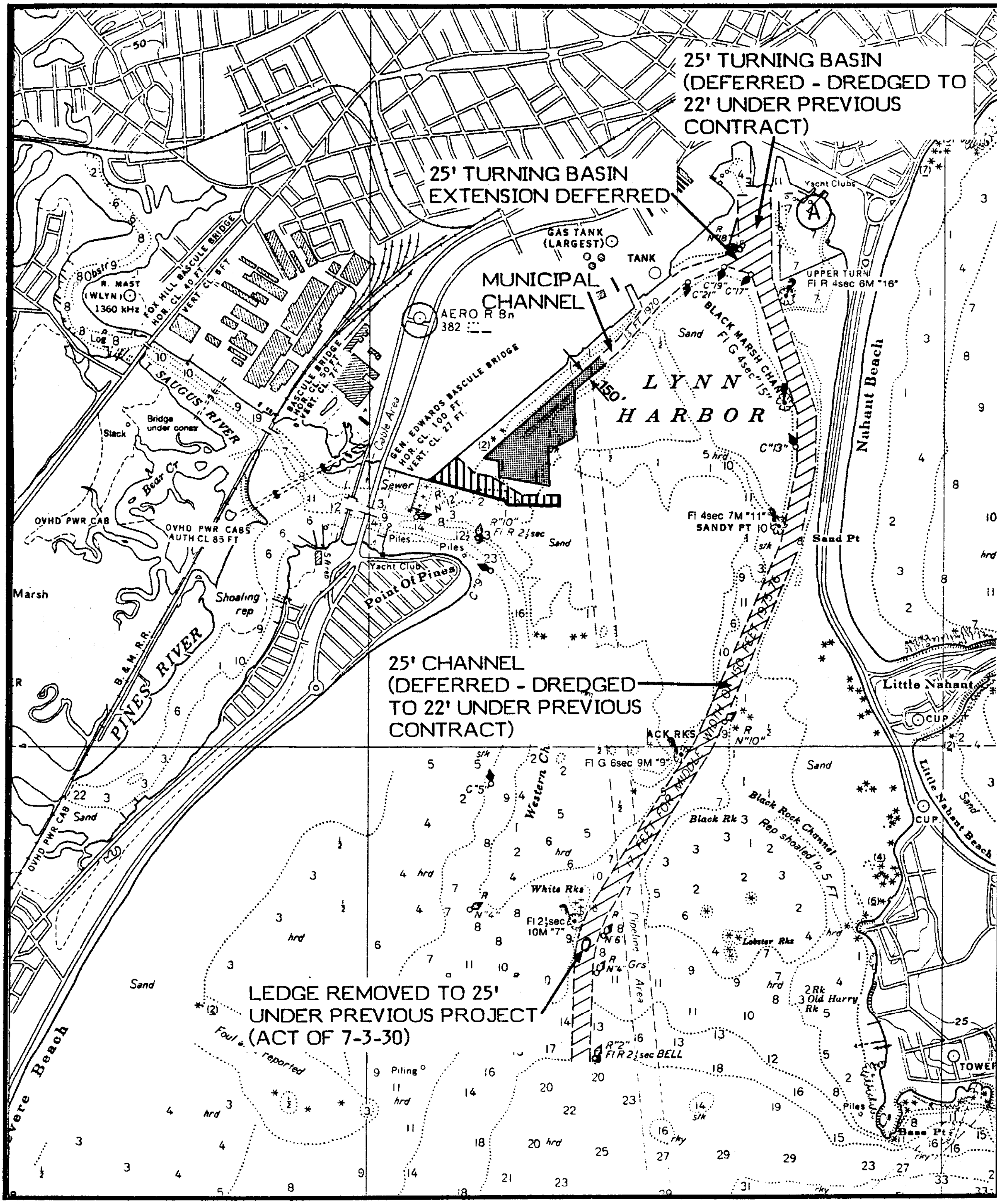

C.O.E. SMALL NAVIGATION PROJECT
Lynn Harbor, Massachusetts
SOURCE: U.S.ACOE 1979

ALTERNATIVE 4

Corps Dredging

Scale 1:25,000

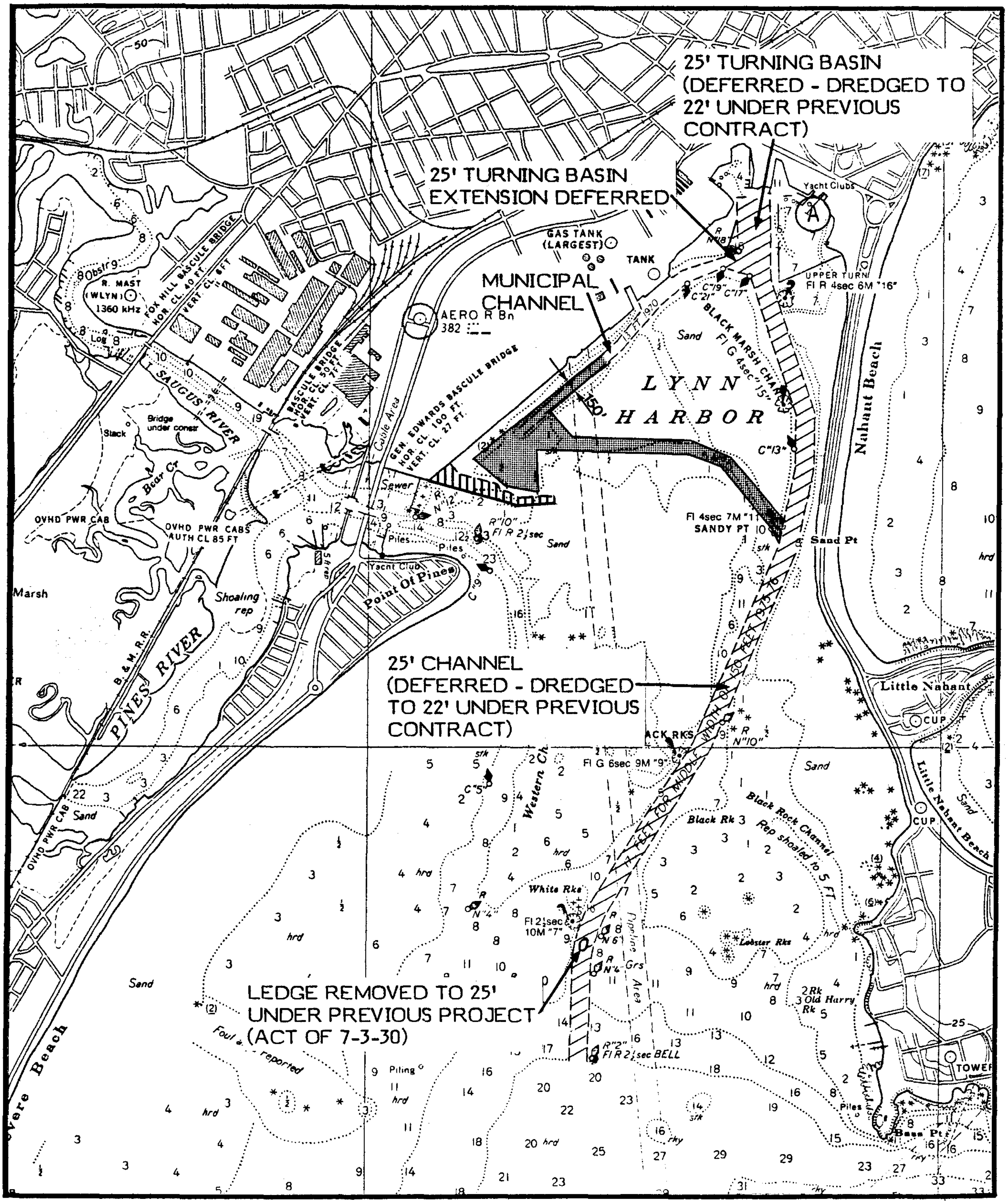
FIGURE 4




C.O.E. SMALL NAVIGATION PROJECT
Lynn Harbor, Massachusetts
SOURCE: U.S.ACOE 1979

Scale 1:25,000

ALTERNATIVE 6
Corps Dredging
Corps Breakwater
To Be Performed By Locals
FIGURE 5




C.O.E. SMALL NAVIGATION PROJECT
Lynn Harbor, Massachusetts
SOURCE: U.S.ACOE 1979

Scale 1:25,000

ALTERNATIVE 7

Corps Dredging
Corps Breakwater
To Be Performed By Locals

FIGURE 6

### 2.2.7.1 Economic Impact of Alternative 7

Net income benefits would be the same as those in Alternative 4 with an additional recreation benefit of $311,875.00. The cost of this alternative would be $9,242,600 with an annual cost of $662,650.00 (U.S. ACOE, 1979).

### 2.2.8 Alternative 8

This Alternative requires construction of a larger breakwater. Two hundred and six acres of anchorage would be dredged (Figure 7).

### 2.2.8.1 Economic Impact of Alternative 8

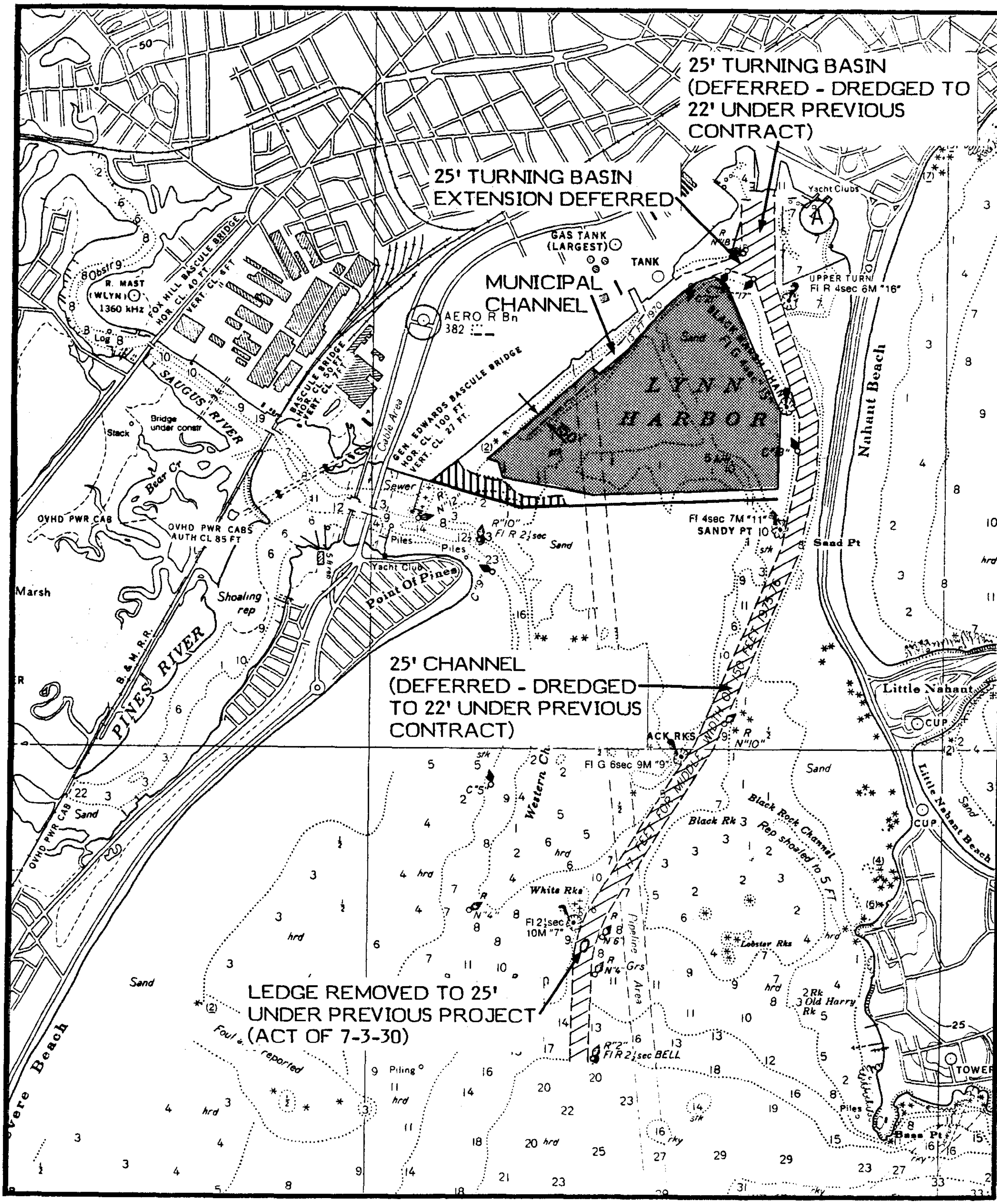
The U.S. ACOE (1979) estimates that net benfits from Alternative 8 would equal $6,555,395.00. The project cost will be $21,963,900.00 or $1,566,250.00 annually.

### 2.2.9 Alternative 9

The final option, Alternative 9, would dredge the Lynn Harbor channel to a depth of -35 ft MLW to allow passage of larger, deeper draft vessels. A large breakwater would be built (Figure 8).

### 2.2.9.1 Economic Impact of Alternative 9

The commercial shipment of commodities may lead to the realization of additional benefits for transportation savings over present modes of transporting those same commodities. However, highway and rail access from the Harbor area is inadequate to handle the distribution of large cargo quantities. In addition, the expansion of Boston Harbor's Massport facility has obviated the need for this type of expansion at Lynn. For these reasons, Alternative 9 will not be considered further.



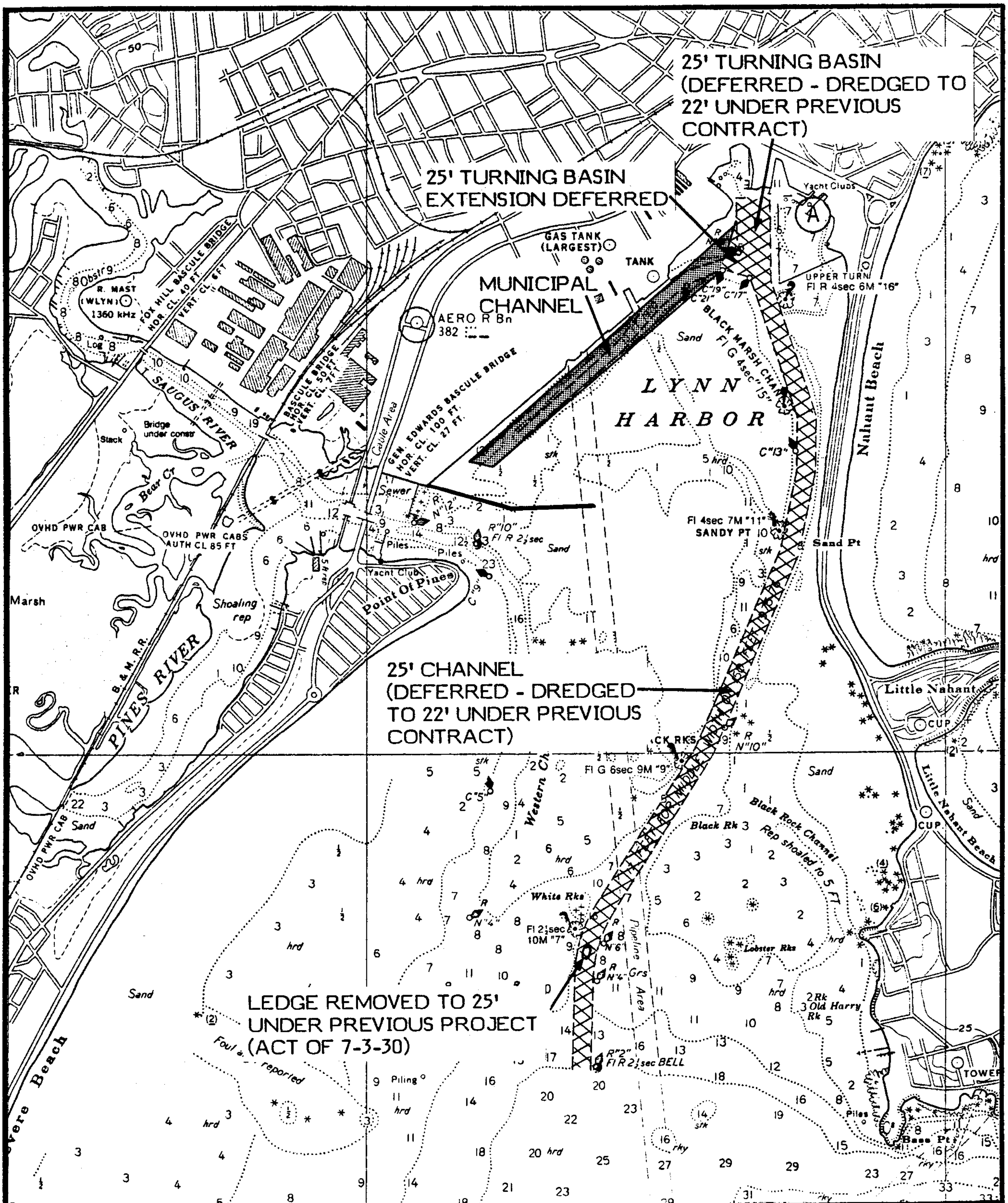

C.O.E. SMALL NAVIGATION PROJECT
Lynn Harbor, Massachusetts
SOURCE: U.S.ACOE 1979

Scale 1:25,000

ALTERNATIVE 8

Corps Dredging
Corps Breakwater
To Be Performed By Locals

FIGURE 7




C.O.E. SMALL NAVIGATION PROJECT
Lynn Harbor, Massachusetts
SOURCE: U.S.ACOE 1979

ALTERNATIVE 9
Improvement Dredging
Corps Dredging
Corps Breakwater
FIGURE 8

Scale 1:25,000

## 2.3 Summary

The various alternatives considered are summarized in Table 3.

Table 3

SUMMARY OF ALTERNATIVES

| Alternative | Cost ($\$ \times 10^6$) | Annual Cost ($\$ \times 10^6$) | Dredge Volume ($yd^3$) | Breakwater | Annual Benefits ($\$ \times 10^6$) |
|---|---|---|---|---|---|
| 1 | 0 | 0 | 0 | No | 0 |
| 2 | 3.1 | 0.2 | 835,000 | No | 6.1 |
| 3 | 6.6 | 0.5 | 835,000 | Yes | 6.1 |
| 4 | 5.4 | 0.4 | 1,296,700 | No | 6.1 |
| 5 | 9.0 | 0.6 | 1,296,700 | Yes | 6.1 |
| 6 | 7.0 | 0.5 | 1,387,042 | Yes | 6.4 |
| 7 | 9.3 | 0.7 | 1,387,042 | Yes | 6.4 |
| 8 | 22.0 | 1.6 | 3,206,000 | Yes | 6.5 |

## 2.4 Alternatives for Dredged Material Disposal

A number of Alternatives for disposal of the dredged materials have been evaluated. They are:

1. Upland disposal

2. Beach nourishment at Revere Beach

3. Use as fill at Lynn and South Boston Naval Annex

4. Ocean disposal at the Boston Foul Area.

### 2.4.1 Upland Disposal

The Lynn sanitary disposal site is located on land adjacent to the Harbor, south of Route 1A. The site is characterized by rutted, bare soil; small stands of Phragmites spp.; and refuse. Rock doves, house sparrows, red-winged blackbirds, and various gulls use the site. Many other species may use the site for temporary cover while migrating.

Disposal of the dredged materials at the landfill between the Saugus and Pines Rivers and at the disposal site south of Route 1 were evaluated and subsequently rejected because of the anticipated volume of dredged material. It is important that a suitable staging area for the unloading, dewatering, and loading of dredged materials be located immediately adjacent to the site. A minimum area of 150 acres to a maximum of 300 acres will be required for this, assuming a 6 ft depth for dewatering. No such area is available at the project location.

### 2.4.2 Beach Nourishment at Revere Beach

Revere Beach forms the eastern border of Broad Sound and Lynn outer Harbor. Like all New England beaches, the shore zone is a dynamic area. The organisms inhabiting the beach, haustorid amphipods (scuds), polychaetes, and mole crabs are adapted to living in a constantly changing environment.

There is a need for material for the replenishment of Revere Beach (Tom Bruha, U.S. ACOE, NED., Personal Communication, 1980). If the material from Lynn Harbor meets the requirements for the beach nourishment project, this disposal method is the environmentally preferred Alternative. The acceptability of dredged material for use in beach nourishment is dependent upon the grain size distribution and the specific gravity of both the dredged material and the receiving beach. Mr. Bruha indicated that the dredged material, in order to be acceptable, must have a specific gravity of not less than 2.5. The sorting coefficient must be less than 2.0. Not more than 5 percent of the sediment may be greater than 4.76mm and not more than 10 percent of the sediment may be finer than .076mm.

The environmental impacts of beach nourishment are minimal if compatible material is used, because beach organisms are adapted to a constantly changing environment. While temporary reduction in population density will be expected to occur in the discharge zone (U.S. Department of the Interior, 1974), organisms from adjoining communities will quickly recolonize the area. The recreational impact of beach nourishment is highly beneficial; beaches are intensively used recreational areas. The cost for beach disposal ranges from \$1.32 to \$4.70 per cubic yard (Mitre, 1979).

### 2.4.3 Use as Fill at Lynn and South Boston Naval Annex

A number of projects are planned for which Lynn will require fill. These include the Lynn Heritage Park and a Hotel Marina complex to be located at the northern part of the Harbor. However, the volume of fill required by these projects is insufficient to warrant further consideration. Massport has a large requirement for high quality fill material at the South Boston Naval Annex. The dredged material could be barged from Lynn to Boston Harbor at a cost of \$4.20 per $yd^3$ (Means, 1980).

Boston Harbor is located on the coast of Massachusetts. The Harbor is formed by a group of outlying islands and the peninsulas of Winthrop and Hull. The Harbor has an area of approximately 50 $mi^2$. The South Boston Naval Annex (SBNA) is one of many underutilized parcels located along Boston's once thriving Inner Harbor waterfront (JMCA, 1980a).

Sediments in the vicinity of the SBNA have a mean grain size of from 0.0625mm to 0.004mm and are classified as silts.

The tidal range in Boston Harbor is 9.5 ft with spring tidal ranges exceeding 11.0 ft. Average current velocities for the Harbor are less than 0.5 kts. The water quality classification of the Harbor is SC according to the Commonwealth of Massachusetts. "Waters assigned to this class are designated for the protection and propagation of fish and other aquatic life and wildlife; and for secondary contact recreation." (Mass. Water Quality Standards, February, 1979).

A large number of finfish species are found in the Harbor. These are listed in Appendix A. Zooplankton and phytoplankton typify those found in New England estuaries. The benthic organisms were studied by the New England Aquarium (JMCA, 1980b) and the communities were characterized by low diversity, small populations, and dominance by Capitella capitata (a polychaete). There are no reported shellfish flats in the area (Massachusetts Division of Marine Fisheries, Personal Communication, cited in JMCA, 1980b).

It is probable that Massport would be willing to purchase the fill obtained from Lynn Harbor, if it meets their requirements, at a nominal fee which would further defray the cost of transport. The cost of trucking from Lynn to Boston is approximately $3.30/yd$^3$ (assuming a 50 ton trucking permit is granted). A staging area, such as that described in Section 2.4.1, will also be required, adding to the cost of this alternative.

### 2.4.4 Ocean Disposal at the Boston Foul Area

The Boston Foul Area is an EPA-approved site for dredged material disposal, located 16.4 nautical miles from Lynn Harbor. It is a circular area 2 nautical miles in diameter with its center at the intersection of lines bearing 71$^{\circ}$ (True) from Boston Lighted Horn Buoy B and 112$^{\circ}$ (True) from Marblehead Light. Preliminary tests of Lynn Harbor sediments demonstrate that they meet the requirements for ocean disposal. The cost of dredging and disposal would be between $5.50 and $8.00 per cubic yard (Means, 1980).

The Boston "Foul Area" is the closest EPA designated ocean disposal site and has a history of being used for the disposal of dredged materials and industrial wastes. The site lies within the Stellwagen Basin. The bottom sediments are clayey silts (Schlee et al., 1973). The site is currently being monitored by the Disposal Area Monitoring System (DAMOS). The 1978 DAMOS report offers the following description of the physiography.

"On the Boston Foul Ground, the only major features are Stellwagen Bank in the northeast corner of the site and a circular mound in the north central portion of the site. Sampling of this mound indicated it was composed of glacial material and is probably related to the same forces that created Stellwagen Bank. The remainder of the site is extremely flat, although a small depression exists near the center of the site. This depression contains fine black spoil material, probably from the Charles River Dam project. However, there is no topographic indication of spoil material." (NUSC, 1978)

DAMOS also investigated bottom currents and concluded that horizontal energy is extremely low and indicative of a nontidal flow area. "The highest 10 percent speed of 14 cm/sec is also low and if real, indicate that currents would not be sufficient to disperse spoils." (NUSC, 1978). Work by Butman (NEA, 1975) has shown that during winter storms bottom currents were of sufficient magnitude potentially to move suspended solids 12.5 miles.

The chemical properties of the Foul Area sediments are presented in Table 4, along with chemical properties of the Lynn Harbor sediment. It will be noted that only copper and mercury concentrations in the Lynn Harbor sediments exceed the concentrations found in the Foul Area sediments.

Table 4

COMPARATIVE CHEMICAL PROPERTIES OF FOUL AREA AND LYNN HARBOR SEDIMENTS

| | Foul Area[1] | Lynn Harbor |
|---|---|---|
| Oil and Grease % | ND | 0.07 |
| Mercury | 0.59 | 0.80 |
| Lead | 60.94 | 41.00 |
| Zinc | 140.44 | 60.80 |
| Arsenic | 13.25 | 3.10 |
| Cadmium | 3.43 | 2.50 |
| Chromium | 73.75 | 57.20 |
| Copper | 21.13 | 24.00 |
| Nickel | 37.56 | 17.60 |
| Vanadium | 53.69 | 42.40 |
| PCBs | 52.15 | ND |

[1]NEA 1975
ND = No Data
Metals and PCBs given in ppm

Water quality of the Foul Area has been evaluated by the New England Aquarium (1975). A seasonal thermocline exists, developing in late April or May and weakening during the late fall. Salinity is relatively constant at 32.2 parts per thousand (ppt) but decreases during the spring. The lowest measured dissolved oxygen level was 6.82 mg/l at the bottom during December. Dissolved oxygen levels are related to primary production and plankton community organics. Nutrient relationships also reflect plankton community growth and die off, particularly for nitrate and phosphorus. Trace metals were within acceptable levels (1.0 ppb); DAMOS studies (1979) show that when mussels taken from near shore are exposed at the Foul Area their tissues exhibit a decrease in heavy metals concentrations. This suggests that the effect of the dredged materials at the site is minimal with regard to dissolved or suspended heavy metals and their impact upon filter feeding organisms.

Biological data from the DAMOS study are given in Appendix A for samples taken in December of 1977 with a dredge at 42° 25' 21.8" and 70° 34' 54.2". These data can be compared with those taken by the New England Aquarium (1975). At that time, samples were dominated by the polychaetes, Spio filcornis and Heteromastus filiformis. Diversity was high while abundance was low. Samples taken by the New England Aquarium in 1975 were dominated by the polychaetes Pronospio malmgreni, Spio filicornis, and Heteromastus filiformis.

Fishing and shellfishing are prohibited in the radius of 1 mile around the site center. Among the fish species which are caught in the area are flounder, cod, dogfish, dab, grey sole, and whiting.

## 3.0 INVENTORY OF THE AFFECTED ENVIRONMENT

In order to provide access to a new marine industrial park in the Town of Lynn, the U.S. Army Corps of Engineers was requested to dredge a portion of the Harbor to a depth of 2.5 ft, to deepen existing channels from 22 ft to 25 ft MLW, and to build a breakwater extending from the mouth of the Pines River toward the center of the Harbor.

### 3.1 Project Area Description

Lynn Harbor is an approximately triangular basin, opening to the south into Broad Sound and Massachusetts Bay. The average depth of the Harbor is 5.1 ft. The Harbor is bounded on the east by two rocky headlands, Nahant and Little Nahant, connected by tombolos to form a 3.2 mile long complex, and bounded on the west by the Lynn waterfront, the Saugus and Pines River Inlet, and Revere Beach (Figure 1).

The shoreline of Lynn Harbor in the project area is bulkheaded along the northern (Lynn) shore, and sand beach on the Revere and Nahant shores, with ledge protruding from the Nahant side. Point of Pines, a sand spit at the mouth of the Saugus River, is a deposit of river sands (Normandeau, 1979).

### 3.2 Sediments

The bottom sediments of Lynn Harbor consist of fine sand and silt covered intermittently by mussel banks. The sand intergrades with mud on the intertidal flats and at the head of the Harbor. The sand is derived from fluvial sediments brought down the Pines and Saugus Rivers, and from glacial sediments that underlie the Harbor.

At several locations on the Harbor bottom, concentrations of boulders and bedrock outcrops (ledges) are located (Chesmore et al., 1972). Seismic reflection profiles conducted in the area three miles east of Nahant showed 30-50 ft of sediments overlying a continuous bedrock base. The bedrock also outcrops as ledges in this region (Raytheon, 1974). Borings in the Saugus marsh provided the data that bedrock occurs between 100 and 200 ft below the surface. The Harbor sediments consist of glacial till and salt marsh peat deposits. The bedrock consists of Carboniferous age argillite, a sedimentary rock. The rock outcrops in Nahant are igneous (gabbro), and sedimentary rocks of Cambrian age.

"Mean concentrations of all chemical constituents are within the Massachusetts Dredge Material classifications of Category 1, Type A, with the exception of mercury, which occur consistently at Category 2 levels (0.6-1.0 ppm). Cadmium, chromium, and vanadium each exceed the Category 1 limits in individual samples, but never exceed Category 2. Percent silt-clay and percent water are at Type B levels in some individual samples, but the means are well within Type A criteria. These criteria are applied by the Massachusetts Division of Water Pollution Control in water quality certification of Federal or State dredging and filling in Commonwealth waters under Section 401 of the Federal Water Pollution Control Act (PL 92-500) and Section 27 (12) of the Massachusetts Clean Waters Act (G.L., c.21, 26-53).

Sediments from Stations A, B, and C (Figure 9) are acceptable for ocean dumping at the "Boston" Dump Site for Dredged Material as evaluated in liquid, suspended solid, and solid phase bioassays (Energy Resources Company, Inc., 1979). Dredged material from Lynn Harbor will comply with Sections 227.5 (Prohibited Materials), 227.6 (Constituents Prohibited as Other than Trace Contaminants), and 227.13 (Dredged Material) of Subpart B, Environmental Impact of U.S. EPA Ocean Dumping Regulations and Criteria (FR 42(7):2462-2490)." (Normandeau, 1979)

### 3.3 Water Quality

"Water quality data are reported in detail in Chesmore et al., (1972); Raytheon (1970, 1971, 1972a, 1972b, 1973); and VTN (1979). The Massachusetts Division of Water Pollution Control has classified Lynn Harbor and the Pines and Saugus Rivers as SB. Waters classified SB are designated as acceptable for recreation, marine fisheries, and shellfishing with depuration. However, all shellfish beds are closed to harvest except a small segment in the Pines River due to gross contamination (MDF, 1972; Personal Communication, 1980).

Water temperature ranges from -2°C to 21°C with maxima (18 to 21°C) July through September and minima (-2 to 0°C) December through March. Salinity ranges from 3 to 34°/oo, with values less than 28°/oo rare and confined to the Saugus and Pines Rivers. This reflects the relatively small influence of freshwater flows in the Harbor. Dissolved oxygen concentration in Lynn Harbor ranges from 6 to 13 mg/l, well above the critical level of 4.0 mg/l (Tables 5 and 6). The range of pH and turbidity values is typical of marine and estuarine waters (Tables 5 and 6).

Nutrient levels are high (Table 7) and phosphate: nitrate ratios are sufficiently high (1:3) that nitrate is apparently the limiting nutrient (Raytheon, 1973; Cochrane et al., 1979). Concentrations of dissolved trace metals are generally low but are apparently subject to extreme short-term increases (Table 13), although the extreme values in April and August, 1972 may be a result of sample contamination or analytical error. Bacterial contamination of Harbor waters is sporadically apparent (Tables 8-12)." (Normandeau, 1979)

Table 5

WATER QUALITY DATA FOR 1968-1969
LYNN HARBOR SHORE STATIONS

| Sample Location | Station No. | pH | Parameter Range DO | Coliform Bacteria* |
|---|---|---|---|---|
| Pond Beach | 1 | 7.5-8.5 | 8.0-10.0 | 20-3,100 |
| Lynn Harbor | 2 | 8.0-8.5 | 8.0-10.0 | |
| Saugus River | 3 | 6.5-8.5 | 7.0-10.0 | 78-160,000 |
| Pines River | 4 | 8.0-8.5 | 7.0-10.0 | 36-16,000 |
| Short Beach | 5 | 7.0-8.5 | 9.0-10.0 | 36-9,500 |

* Most probable number per 100 ml.

Source: Chesmore, Brown, and Anderson, 1972 (in VTN), Normandeau, 1979.

Table 6

WATER QUALITY DATA
LYNN HARBOR, 1972

| Sample Location | Depth | BOD (mg/l $O_2$) | Parameter Range DO (mg/l $O_2$) | Turbidity (JTU) |
|---|---|---|---|---|
| Power Plant Site | Surface<br>Bottom | 0.1-5.1<br>0.1-5.3 | 6.1-11.1<br>6.1-12.3 | 0.3-3.4<br>0.3-5.3 |
| Saugus River Mouth | Surface<br>Bottom | 0.1-6.6<br>0.1-6.2 | 5.4-12.1<br>5.4-11.5 | 0.4-5.9<br>0.4-5.4 |
| Lynn Sewage Outfall | Surface<br>Bottom | 0.5-6.9<br>0.1-6.2 | 7.2-13.2<br>6.6-11.8 | 0.3-6.8<br>0.3-8.5 |

Source: Raytheon, 1973 (in VTN), Normandeau, 1979.

Table 7

LYNN HARBOR TOTAL NUTRIENTS
NITRATES AND PHOSPHORUS, 1972
( g/l)

| Sampling Location | Depth | Winter Average | Spring Average | Summer Average | Fall Average | Annual Average |
|---|---|---|---|---|---|---|
| Power Plant Site | Surface | 241 | 72 | 58 | 122 | 105 |
| | Bottom | 135 | 53 | 54 | 120 | 83 |
| Saugus River Mouth | Surface | 253 | 103 | 73 | 171 | 131 |
| | Bottom | 162 | 79 | 66 | 142 | 103 |
| Lynn Sewage Outfall | Surface | 350 | 99 | 62 | 135 | 132 |
| | Bottom | 182 | 44 | 60 | 99 | 83 |

Source: Raytheon, 1973, Normandeau, 1979.

Table 8

WATER QUALITY FOR 1974
COASTAL BEACH SURVEY

| Sample Location | Station No. | Total Coliform | Fecal Coliform |
|---|---|---|---|
| Stacy Brook | 1 | 0-7,000 | 0-600 |
| Kings Beach | 2 | 100-600 | 0-600 |
| Lynn Beach | 3 | 20-700 | 0-0 |
| Nahant Beach | 4 | 80-900 | 0-80 |
| Revere Beach | 5 | 100-900 | 0-20 |
| Short Beach | 6 | 100-800 | 0-40 |

Source: Metropolitan District Commission, 1974, (in VTN), Normandeau, 1979.

Table 9

WATER QUALITY FOR 1975
COASTAL BEACH SURVEY

| Sample Location | Station No. | Total Coliform | Fecal Coliform |
|---|---|---|---|
| Stacy Brook | 1 | 0-1,300 | 0-30 |
| Kings Beach | 2 | 0-400 | 0-10 |
| Lynn Beach | 3 | 0-700 | 0-10 |
| Nahant Beach | 4 | 0-600 | 0-10 |
| Revere Beach | 5 | 0-600 | 0-10 |
| Short Beach | 6 | 0-300 | 0-10 |

Source: Metropolitan District Commission, 1975, (in VTN), Normandeau, 1979.

Table 10

WATER QUALITY FOR 1976
COASTAL BEACH SURVEY

| Sample Location | Station No. | Total Coliform | Fecal Coliform |
|---|---|---|---|
| Stacy Brook | 1 | 0-0 | 0-0 |
| Kings Beach | 2 | 0-200 | 0-10 |
| Lynn Beach | 3 | 0-400 | 0-20 |
| Nahant Beach | 4 | 0-400 | 0-20 |
| Revere Beach | 5 | 0-200 | 0-20 |
| Short Beach | 6 | 0-100 | 0-0 |

Source: Metropolitan District Commission, 1976, (in VTN), Normandeau, 1979.

Table 11

WATER QUALITY FOR 1977
COASTAL BEACH SURVEY

| Sample Location | Station No. | Total Coliform | Fecal Coliform |
|---|---|---|---|
| Stacy Brook | 1 | 0-80,000 | 0-20 |
| Kings Beach | 2 | 0-300 | 0-2 |
| Lynn Beach | 3 | 0-200 | 0-2 |
| Nahant Beach | 4 | 0-300 | 0-2 |
| Revere Beach | 5 | 0-200 | 0-2 |
| Short Beach | 6 | 0-100 | 0-2 |

Source: Metropolitan District Commission, 1977, (in VTN), Normandeau, 1979.

Table 12

WATER QUALITY FOR 1978
COASTAL BEACH SURVEY

| Sample Location | Station No. | Total Coliform | Fecal Coliform |
|---|---|---|---|
| Stacy Brook | 1 | 0-80,000 | 0-9,000 |
| Kings Beach | 2 | 0-800 | 0-10 |
| Lynn Beach | 3 | 0-600 | 0-10 |
| Nahant Beach | 4 | 0-400 | 0-20 |
| Revere Beach | 5 | 0-600 | 0-10 |
| Short Beach | 6 | 0-1,900 | 0-20 |

Source: Metropolitan District Commission, 1978, (in VTN), Normandeau, 1979.

Table 13

LYNN HARBOR TRACE METALS, 1972
($\mu g/l$)

| Power Plant Site | Concentration | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Metal | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| Cadmium | 1.0 | 530.0 | 5.0 | 5.0 | 0.7 | 0.5 | 0.6 | 0.3 | 1.3 | 1.2 |
| Chromium | 10.0 | 90.0 | 10.0 | 10.0 | 10.0 | 10.0 | 5.0 | 5.0 | 14.0 | 2.6 |
| Copper | 2.0 | 0.01 | 58.0 | 4.0 | 4.7 | 11.0 | 2.0 | 1.0 | 4.3 | 3.1 |
| Lead | 5.0 | 420.0 | 20.0 | 5.0 | 38.0 | 140.0 | 12.0 | 10.0 | 20.0 | 12.0 |
| Nickel | 4.0 | 400.0 | 29.0 | 5.0 | 5.0 | 5.0 | 5.0 | 8.0 | 15.0 | 7.1 |
| Zinc | 8.0 | 6.0 | 6.0 | 28.0 | 48.0 | 360.0 | 12.0 | 6.0 | 27.0 | 28.0 |
| **Outer Nahant Bay** | **Concentration** | | | | | | | | | |
| Metal | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| Cadmium | 1.0 | 360.0 | 5.0 | 5.0 | 3.1 | 0.2 | 0.4 | 0.3 | 0.7 | 0.6 |
| Chromium | 10.0 | 80.0 | 10.0 | 10.0 | 10.0 | 10.0 | 5.0 | 5.0 | 11.0 | 1.8 |
| Copper | 2.0 | 0.01 | 10.0 | 6.0 | 2.3 | 1.2 | 1.0 | 1.0 | 6.8 | 2.4 |
| Lead | 5.0 | 430.0 | 5.0 | 5.0 | 10.0 | 10.0 | 10.0 | 15.0 | 31.0 | 8.0 |
| Nickel | 3.0 | 376.0 | 24.0 | 5.0 | 5.0 | 5.0 | 4.0 | 4.0 | 9.8 | 6.0 |
| Zinc | 16.0 | 50.0 | 14.0 | 3.0 | 40.0 | 105.0 | 3.0 | 3.0 | 29.0 | 20.0 |

Source: Raytheon, 1973, Normandeau, 1979.

## 3.4 Hydrodynamics

The tides in Lynn Harbor are regular and semi-diurnal. The mean range is 9.2 ft and the spring range is 10.7 ft. Since the average MLW depth is 5.1 ft, there is a 64 percent exchange of water in each tidal cycle. Tidal velocies in the Harbor are very low (maximum flood and ebb = 0.3 kts) with an eight hour period of flood and a four hour period of ebb flow. At Sandy Point, ebb and flood periods are equal, with maximum velocities at 0.6 kts. In the Saugus River Inlet, maximum ebb velocities reach 1.4 kts and maximum flood reaches 0.9 kts due to the tidal constriction of the inlet throat (NOAA, undated).

The highest frequency of surface currents is directed northwest and the highest frequency of bottom currents is southeast (Raytheon, 1979). Drogues released at the existing sewage outfall during flood tides drifted into Lynn Harbor until seaward of Pines-Saugus River Inlet. During ebb tides, drogues moved west toward Winthrop Headland.

Storm surges can increase the tidal range by up to 50 percent. Table 14 presents significant historical surge heights.

Table 14

STORM SURGE DATA

| Date | Height of Surge above MHW (ft) |
|---|---|
| 1922 | 5.9 |
| 1959 | 4.7 |
| 1961 | 4.7 |
| 1967 | 4.0 |
| 1976 | 5.6 |

Wind data were obtained from the NOAA meteorological monitoring station at Logan Airport. Prevailing winter winds are northwest to west-northwest. During other seasons of the year, southwest winds prevail.

Raytheon (1974) reported mean wave height from 1 to 10 ft with 6 to 14 second periods. In order to determine probable wave heights within the Harbor, JMCA (1980) used graphical techniques outlined in CERC (1973). The study showed that Lynn Harbor is well protected from waves originating in Cape Cod Bay on southeast winds by the following factors:

1. A regional divergence of wave energy as the wave fronts approach Lynn Harbor;

2. A shift in orientation of wave fronts from southeast to east-southeast;

3. The resulting protection of the Harbor by the Nahant tombolo complex;

4. Further divergence of wave energy as the wave fronts enter Lynn Harbor;

5. Diffraction, or the spreading of wave energy along wave crests resulting from the shadow zone created by Nahant; and

6. The effects of the intertidal flats acting as a natural breakwater at low and mid-tide, and reducing energy at high tide.

Wave heights at Lynn Harbor will thus be greatly reduced. Wave height reduction due to refraction is presented in Table 15 for a high tide case.

Table 15

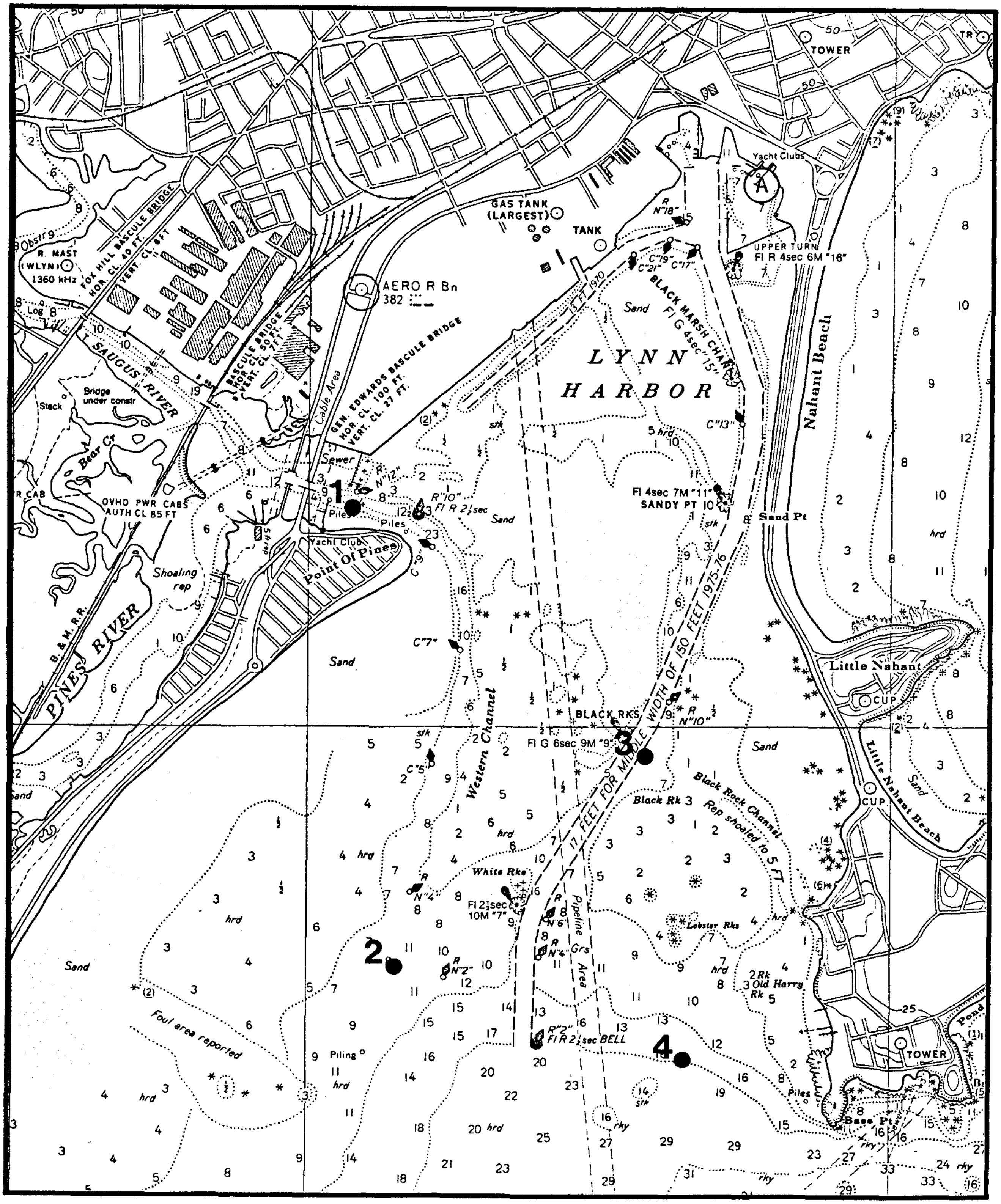
WAVE HEIGHTS DUE TO REFRACTION

| Wave Height at Mouth of Boston Harbor (ft) | Wave Height at Tip of Proposed Breakwater Lynn Harbor (ft) |
|---|---|
| 4 | 2 |
| 6 | 3 |

These estimates are further reduced by the action of the Harbor's intertidal flats to protect the Inner Harbor from all (low tide) or some (high tide) incoming wave energy. Wave heights under hurricane force winds are projected to be less than 2 to 3 ft in Lynn Inner Harbor.

In order to determine the current regime in the Harbor, a hydrographic monitoring program was established (Ocean Surveys, 1980; JMCA, 1980). Four continuously recording current meters were deployed for the sampling period from June 12, 1980 to June 21, 1980. This nine day period was scheduled to encompass both spring and neap periods so both maximum and minimum monthly currents were recorded.

Each meter was located four feet above the bottom in water depths shown on Table 16 and at the locations illustrated in Figure 10.




C.O.E. SMALL NAVIGATION PROJECT
Lynn Harbor, Massachusetts

SOURCE: Ocean Surveys, Inc.

LOCATION of HYDROGRAPHIC MONITORING STATIONS

CURRENT METERS AT STATIONS 1,2,3,4

TIDE GAUGE AT STATION 2

Scale 1:25,000

FIGURE 10

Table 16

CURRENT METER DEPTHS

| Hydrographic Station | MLW Depth (ft) |
|---|---|
| 1 | 14 |
| 2 | 8 |
| 3 | 18 |
| 4 | 14 |

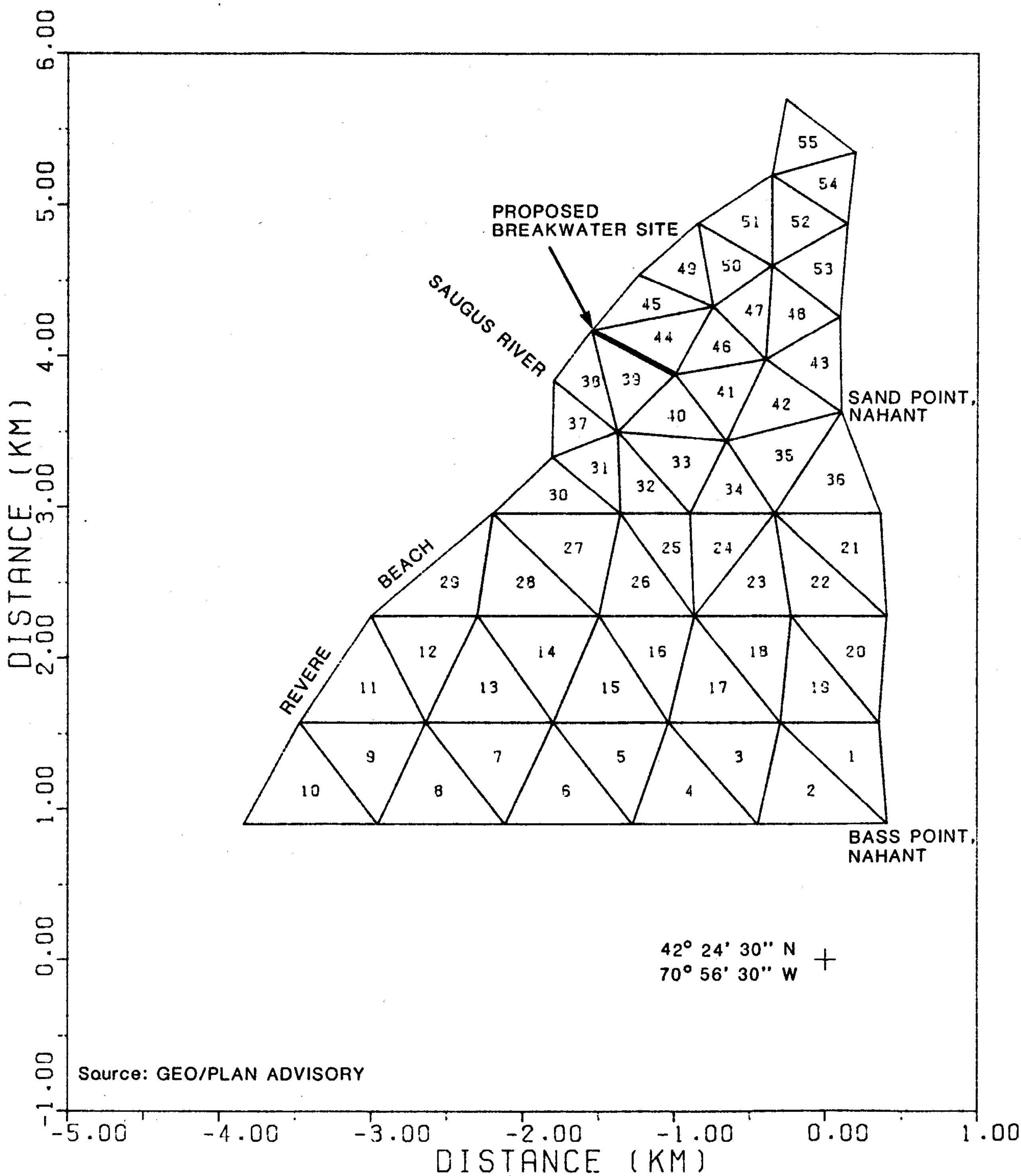
Continuous in situ monitoring of tide height took place at Station 2 from June 12 to July 14, 1980. Heights were recorded by a SEA DATA TDR-1 tide gauge. This pressure-sensing device recorded at ten minute intervals by averaging 160 seconds of data to produce a water level reading which would be unaffected by wind waves.

These data were input into a two-dimensional finite element hydrodynamic model to simulate circulation and water elevation throughout Lynn Harbor. The basis of this model is described in Chen (1978). A finite element network (Figure 11) was developed for Lynn Harbor using National Ocean Survey Hydrographic Sounding Sheet H9134. Each element in the grid ranges in size from approximately 500 meters to 700 meters. Geographic locations and the site of the proposed breakwater are presented in Figure 11. The cross (+) on the grid locates the point 42° 24' 30"N x 70° 56' 30"W. The model was run at a time increment of 20 seconds throughout a complete spring tidal cycle (JMCA, 1980).

The ebb tide circulation is dominated by a strong southerly flow of the water in Lynn Harbor along Revere Beach. The major input of water to the Harbor is at the Saugus River Inlet. After flowing out of the inlet, there is a divergence in the major flow due to the tidal flats. Most water flows out the Western Channel. A lesser volume of water flows through the channel at the northern border of the Harbor, around the tidal flats, and seaward in the main navigation channel at the east side of the Harbor.

Maximum ebb velocities occur late in the tidal cycle (Hours 5-6). This is due to the lowering water level which will diminish the size of the channels as the ebb tide progresses, resulting in higher velocities. This effect is augmented by the large volume of water in the Saugus River that must drain (Hour 7), and by the presence of tidal flats, which severely restrict channel size during late ebb.

The effects noted above also serve to increase the duration of the ebb tide relative to the flood tide, causing an asymmetry. Because of this extended period of ebb flow within the Harbor, the duration of low water slack is very short, since the tides in the region have begun to flood while Lynn Harbor is still ebbing.




C.O.E. SMALL NAVIGATION PROJECT
Lynn Harbor, Massachusetts

FINITE ELEMENT GRID
for LYNN HARBOR

FIGURE 11

After a rapid reversal of tides (Hour 8), the flood tides begin gaining velocity immediately. The flood currents have a flow pattern similar to the ebb, although the direction is reversed. Most water moves north along Revere Beach. At the Inner Harbor, flow divides and either moves up the Western Channel or is diverted around the tidal flats to follow a circular path along the eastern navigation channel and north border of the Harbor towards the Saugus River Inlet. The high water slack is approximately one hour in duration, which may promote sedimentation of suspended material.

The confluence of flood currents and bifurcation of ebb currents occur at the proposed breakwater site. Both the duration and velocity of the ebb tide are greater than that of the flood. This asymmetry of tidal flow is common in constricted areas since, as flood velocities increase, water level rises. Therefore, a larger volume of water is transported in less time. During the ebb tide, as velocities increase, the water level falls, resulting in smaller flow channels. Hence, the ebb must flow faster and/or longer to discharge the same amount of water as that brought in on the flood tide.

## 3.5 Biology

Neither upland ecosystems nor wetlands will be directly affected by the project. The aquatic ecosystems have been studied in relation to a number of projects within the Harbor (Cochrane *et al.*, 1972; Raytheon, 1972, 1973, 1971, 1978; Tash, 1970; Houseman, 1980 unpublished). Relevant species lists are presented in Appendix A.

### 3.5.1 Phytoplankton

"Studies conducted in 1970-1974 by Raytheon (1979) found 59 phytoplankton genera; 32 genera were diatoms, the dominant phytoplankton group in Lynn/Saugus Harbor. *Chaetoceros*, *Skeletonema*, *Leptocylindrus*, and *Rhizosolenia* were most abundant. Total densities ranged from $10^3$ to $4 \times 10^6$ cells/liter and averaged approximately $7.5 \times 10^5$ cells/liter. A gross seasonal trend of reduced abundance and species richness in winter and maximum abundance and species richness in summer and fall was apparent. This pattern is repeated in the concentration of chlorophyll. Dinoflagellates were abundant in summer and fall; *Peridinium* sp. was common in summer." (Normandeau, 1980)

Although *Gonyaulax tamarensis* was not identified in Harbor samples Massachusetts North Shore shellfishing had periodically been closed due to blooms of this paralytic shellfish poisoning agent (Raytheon, 1979).

An apparent inverse correlation exists between phytoplankton density and nitrate concentration; phosphate exhibits no distinct seasonal cycle in Lynn-Saugus Harbor (Normandeau, 1980).

### 3.5.2 Macrophytes

"No quantitative data are available on macrophyte populations in Lynn Harbor. A floral species list (Chesmore et al., 1972) is presented in Appendix A. Cochrane et al. (1970) studied the Harbor in response to excessive (eutrophic) *Ulva lactuca* production and subsequent decay. Eelgrass (*Zostera marina*) is reportedly common in shoal areas." (Normandeau, 1980)

### 3.5.3 Zooplankton

"Raytheon surveyed zooplankton in Lynn Harbor 1970-1974 and identified 238 species. Typical genera included *Acartia*, *Calanus*, *Centropages*, *Temora*, *Tortanus*, *Idotea*, *Neomysis*, and *Sagitta*. *Podon*, coelenterates and fish larvae occurred seasonally. Because of the large (500 m) mesh sized used, no quantitative estimate of zooplankton abundance can be made." (Normandeau, 1980)

## 3.6 Benthos

Chesmore et al., (1972) noted the presence of other taxa in their 1969 *Mya* survey (Appendix A) and resurveyed the "Mull Free" flat in 1978. Raytheon (1971, 1972, 1973) collected benthic grab samples at the power plant site, Saugus River mouth, Lynn sewer discharge at a site on the central Harbor mussel shoals (Appendix A) and maintained successional panels at two sites. Benthic invertebrates were also enumerated in Raytheon's bottom trawls (Appendix A) (Normandeau, 1980). A project-specific study was initiated by the U.S. Army Crops of Engineers.

### 3.6.1 Clam Flats

"Productive clam (*Mya arenaria*) flats occurred over 439.9 acres of intertidal area in Lynn Harbor, with a 1971 mean standing crop of 96.2 bushels per acre of intermediate and "legal" (length 51mm) clams. Appendix A presents the distribution of flats and clam densities for each flat. Flats within the project area comprised 33.4 percent of the standing crop and 32.5 percent of the productive acreage. The Wreck and Mull Free were relatively high in density, Churchills and Causeway were about average and Point of Pines ranked 20th among 22 stations in clam density. A 1978 resurvey of the Mull Free flat indicated that the standing crop had not changed significantly although the size/age frequency distribution was very different in 1978 from the kind of distribution evident in 1971.

It is possible that the central mussel shoals were once productive clam flats which evolved into their present "climax community" through a successional process.

### 3.6.2 Intertidal Fauna

Chesmore et al. (1972) found blue mussels (Mytilus edulis), duck clams (Macoma balthica), clam worms (Nereis sp.) and tellin shells (Tellina agilis) on the clam flats they sampled. Raytheon's Station 9 (Appendix A) was characterized by Mytilus edulis, Littorina littorea and Mya arenaria (Raytheon, 1973). VTN cites Raytheon (1972), stating that the green crab (Carcinus maenas) was also abundant in the Lynn Harbor intertidal zone." (Normandeau, 1980)

### 3.6.3 Subtidal Fauna

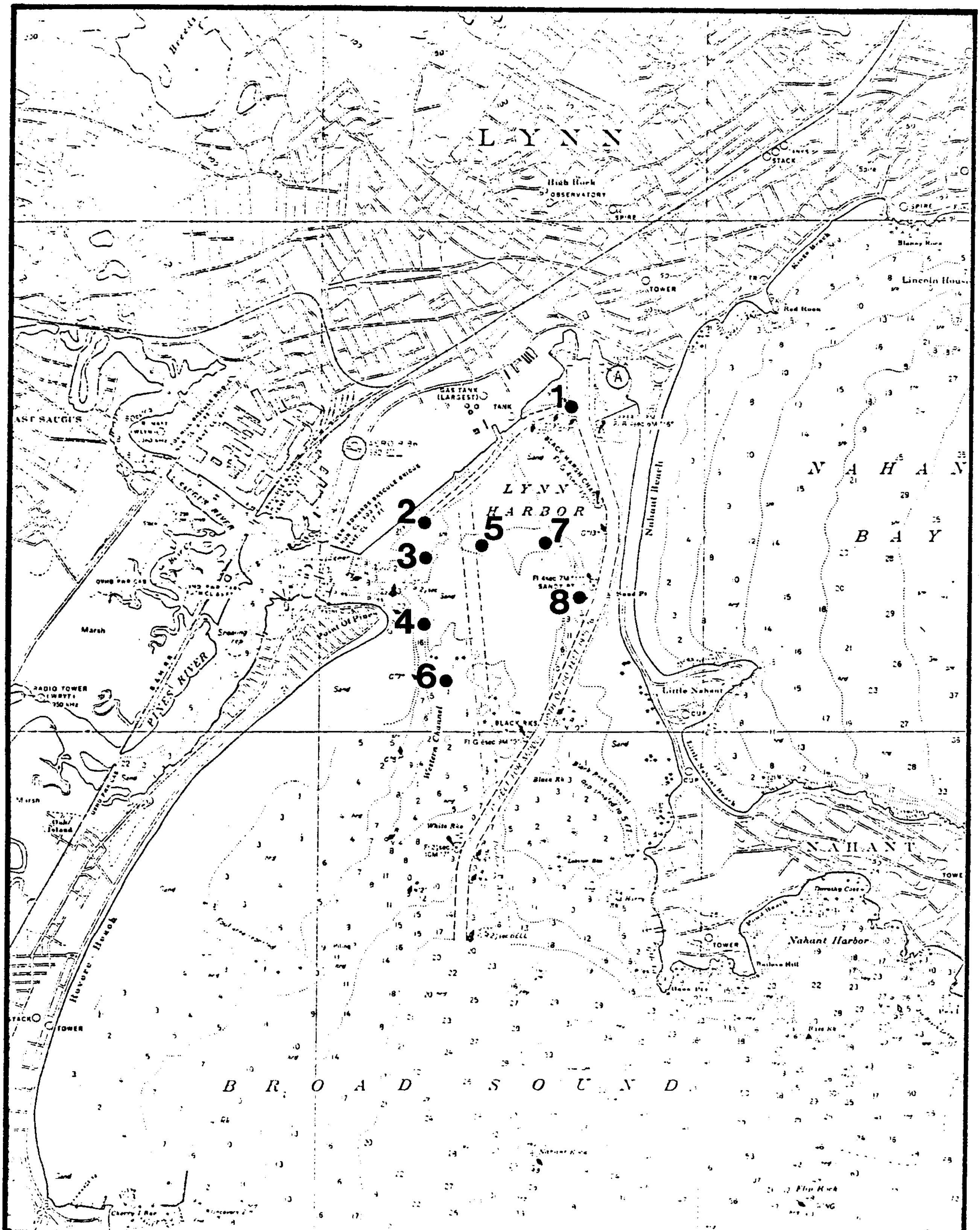
A project-specific survey of benthic fauna was made by Jason M. Cortell and Associates Inc. and Taxon Inc. on the June 12, 1980. A chart showing sampling station locations is given in Figure 12. A 1/25 $m^2$ Van Veen grab was used for collection. Five replicates were collected at each of the eight stations. The samples were returned to the laboratory where they were sieved through a 0.5mm screen and fixed and preserved for subsequent analysis. The contents of each replicate were sorted, identified to species where possible, and enumerated. Table 17 presents the summarized results for each sampling station. Replicate results are presented in Appendix A. Data analyses are given in Table 18. Structural indices are explained in Table 19.

#### 3.6.3.1 Station 1

Station 1, a black mud sediment, contained only nine species. These were fairly evenly distributed ($J = 0.8$). The two most dominant species, Mytilus edulis and Capitella sp. comprise 44 percent of the total sample. Mytilus edulis, the blue mussel, is a ubiquitous bivalve found commonly in estuarine waters along the eastern U.S. coast. According to Rosenberg (1978), this species is highly tolerant of polluted conditions. Capitella sp. is also well known for its ability to tolerate extreme environmental stress and has often been used as an indicator of high organic load (Rosenberg, 1978). Shannon-Weiner diversity at this station was high but this is because the few species were evenly distributed and abundance was low.

#### 3.6.3.2 Station 2

Station 2 had grey mud sediment and contained 28 species. Capitella sp. and Polydora ligni were the two most dominant species and comprised 73 percent of the total number of individuals in the sample. While Polydora ligni is known as an opportunistic, pollution tolerant organism (Rosenberg, 1978), it is also found in stable sand areas covered by algal mud (Gray, 1976), as well as being a member of the hard bottom "aufwuchs" biocoenosis in pristine waters (Field, 1979).




C.O.E. SMALL NAVIGATION PROJECT
Lynn Harbor, Massachusetts

Sampling Station Locations
June, 1980

● Benthic Sampling Stations

Source: JASON M. CORTELL and ASSOCIATES INC.

0' 1000' 2000'

FIGURE 12

Table 17

STATION SUMMARY
LYNN HARBOR SAMPLING
JUNE, 1980

| Species | Station | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| *Campanularia* sp. | | | | x | | | | x |
| *Podocoryne carnea* | | | | x | | | | |
| *Thuiaria argentea* | | | | x | x | | | |
| *Turbellarian* unid. | | 1 | | | | | | |
| *Nemertean* unid. | | | | 5 | | | | |
| *Amphiporus bioculatus* | | | | 11 | | | | |
| cf *Cerebratulus* sp. | | | | 1 | | | | |
| *Tubulanus pellucidus* | | | | 1 | | | | |
| *Oligochaete* unid. | 7 | 29 | 35 | 84 | 4 | 21 | 5 | 5 |
| *Harmothoe* sp. | | | | 3 | | | | |
| *Harmothoe extenuata* | | | | 2 | | | | |
| *Harmothoe imbricata* | | | 2 | | | 2 | 13 | |
| *Sigaloinid* unid. | | 1 | | | | | | |
| *Pholoe minuta* | | | 11 | 2 | 3 | 1 | 1 | 1 |
| *Eteone longa* | | 43 | 71 | 9 | 10 | | 12 | 4 |
| *Phyllodoce* nr. *groenlandica* | | 7 | 9 | 1 | | | | |
| *Phyllodoce maculata* | | 8 | 9 | 3 | | 1 | 1 | |
| *Autolytus* sp. | | | | 5 | | | | |
| *Exogone dispar* | | | | | 4 | 1 | 1 | |
| *Exogone hebes* | | | 4 | 324 | 4 | 7 | | 6 |
| *Nereis virens* | | 20 | 57 | 1 | 12 | | 5 | 1 |
| *Nephtys caeca* | | 11 | 3 | 2 | 19 | 8 | 2 | 2 |
| *Nephtys incisa* | | 1 | | | | | | |
| *Dorvillea caeca* | | | | 13 | | | | |
| *Terebellid* unid. | | | | 1 | | | | |
| *Polycirrus* sp. | | | | 1 | | | | |
| *Spionid* unid. | | | | | | | | 3 |
| *Polydora* sp. | 1 | 1 | | | | | | |
| *Polydora ligni* | 8 | 289 | 612 | 78 | 175 | 105 | 7 | 11 |
| *Polydora websteri* | | 6 | | | | | | |
| *Prionospio malmgreni* | | | 1 | | | | | |
| *Scolecolepides viridis* | 3 | 37 | 90 | 103 | 940 | 35 | | 4 |
| *Scolelepis squamata* | | | 1 | 2 | 1 | | | 1 |
| *Spiophanes bombyx* | | | | | | | | 40 |
| *Streblospio benedicti* | 1 | 18 | 41 | 1 | | 1 | | |
| *Tharyx acutus* | 2 | 32 | 53 | 81 | 21 | 60 | 1 | 140 |
| *Scoloplos* sp. | | 8 | | | | 1 | | |
| *Scoloplos acutus* | | | 9 | 1 | | 2 | | |
| *Scoloplos fragilis* | | 3 | 1 | 1 | | | | |
| *Aricidea jeffreysii* | | | 1 | 1953 | 7 | 450 | 1 | 68 |
| *Paraonis fulgens* | | | 1 | 3 | 90 | 46 | 1 | |

Table 17
(Cont.)

STATION SUMMARY
LYNN HARBOR SAMPLING
JUNE, 1980

| Species | Station 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| Amastigos n. sp. | | | | 4 | 5 | 2 | | 4 |
| Capitella spp. | 12 | 666 | 4623 | 578 | 531 | 78 | 342 | 5 |
| Mediomastus ambiseta | | | | | | | | 2 |
| Polygordius sp. | | | | 297 | 1 | 1 | | 2 |
| Gastropod unid. | | | | 1 | | | | |
| Crepidula convexa | | | | | | | 1 | 1 |
| Crepidula fornicata | | | | | | 3 | 1 | 1 |
| Crepidula plana | | | | 2 | | | | 1 |
| Doto coronata | | | | 4 | | | | |
| Lacuna vincta | | | | | | | 5 | |
| Littorina littorea | | | | | | | 23 | 1 |
| Lunatia heros | | | | 3 | | 3 | | |
| Nassarius trivittatus | | | | 2 | 1 | 2 | 1 | |
| Ensis directus | | 2 | | | | 2 | | |
| Gemma gemma | | | | 7 | | 4 | | |
| Hiatella arctica | | | | 1 | | | | |
| Macoma sp. | | 3 | 2 | | | | | |
| Mytilis edulis | 12 | 7 | 96 | 56 | 14 | | 76 | 7 |
| cf. Pandora gouldiana | | | | 3 | | | | |
| Petricola pholadiformis | | 1 | 1 | 23 | | | | |
| Spisula solidissima | | | 2 | 18 | | 22 | | |
| Tellina agilis | 2 | 48 | 65 | 181 | 67 | 360 | 14 | 44 |
| Oxyurostylis smithi | | 1 | 10 | 1 | 15 | 47 | | |
| Edotea triloba | | 1 | 15 | | 6 | 26 | | |
| Idotea phosphorea | | | | 2 | | | | |
| Jaera marina | | | | | | | 1 | |
| Leptochelia savignyi | | | | 25 | | | | |
| Carcinus maenas | | | | | 1 | | 5 | |
| Crangon septemspinosa | | | | | 1 | | | |
| Pagurus acadianus | | | | 1 | | | 1 | 6 |
| Aeginina longicornis | | | 5 | 357 | | 37 | 3 | |
| cf. Corophium bonelli | | | | | | | | 1 |
| Corophium tuberculatum | | 2 | 19 | 6 | 6 | 3 | | 3 |
| Gammarellus angulosus | | | | | | 3 | | |
| Gammarus sp. | | | 5 | | 2 | | | 4 |
| Gammarus mucronatus | | | 4 | 1 | | 3 | | 1 |
| Gammarus oceanicus | | | | 1 | | | | 1 |
| Ischyrocerus anguipes | | | | 20 | | 1 | 2 | |
| Jassa falcata | | | | | | | | 1 |
| cf. Metopella angusta | | | | | | | | 1 |
| Photus macrocoxa | | | 2 | | | | | |

Table 17
(Cont.)

STATION SUMMARY
LYNN HARBOR SAMPLING
JUNE, 1980

| Species | Station | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Phoxocephalus holbolli | | 1 | 1 | 51 | | 6 | | |
| Proboloides holmesi | | | | 1 | | | 1 | 4 |
| Unciola irrorata | | | 2 | 79 | 10 | 2 | 8 | 20 |
| Unciola serrata | | | | | | | | 1 |
| Balanus sp. | | | | 2 | | | 3 | |
| Balanus balanoides | | | | | | | | 6 |
| Balanus balanus | | | | 6 | | | | 21 |
| Ostracod unid. | | | | | | 1 | | |
| Cribrilina punctata | | | | x | | | | |
| Cryptosula pallasiana | | | | x | | | | x |
| Asterias forbesi | | | | | | | 1 | |
| Mya arenaria | | 4 | 16 | 1 | | 1 | | |
| Nephtys picta | | | | | | 2 | | |

Table 18

STRUCTURAL INDEX SUMMARY: LYNN HARBOR SAMPLING
JUNE, 1980

| Station No. | No. of Species | H' | J | MDI | Dominant Species |
|---|---|---|---|---|---|
| 1 | 9 | 2.8 | .8 | 44 | Capitella/Mytilus |
| 2 | 28 | 2.5 | .5 | 73 | Capitella/Polydora ligni |
| 3 | 35 | 1.5 | .3 | 88 | Capitella sp. |
| 4 | 63 | 3.0 | .5 | 57 | Aricidea jeffreysii |
| 5 | 27 | 2.3 | .5 | 75 | Scolecolepido viridis |
| 6 | 37 | 3.1 | .6 | 60 | Aricidea jeffreysii |
| 7 | 28 | 2.1 | .4 | 79 | Capitella sp. |
| 8 | 37 | 3.5 | .7 | 49 | Tharyx acutus |

H' Shannon Weiner Diversity

J Pielous Evenness

MDI McNaughton's Dominance Index

Sample area equals 0.2 meters$^2$

Table 19

STRUCTURAL INDICES

| Structural Measurement | Abbreviation | Reference | Description |
|---|---|---|---|
| McNaughton's Dominance Index | MDI | McNaughton | This index is a measure of how much the community is dominated by the two most numerous organisms in the community. |
| Shannon-Weiner Diversity | H' | Shannon and Weaver, 1949 | Derived from information theory, this is a measure of the number of species in the community and the way these species are distributed within the community. It is the most commonly used diversity index. |
| Eveness | J' | Pielou, 1975 | A diversity measure which combines both the number of species and the evenness of their distribution in one measure. J' is a separate measure of eveness. |
| Abundance | A | | Number of individual organisms in each sample. |

### 3.6.3.3 Station 3

Station 3 is in shallow water northeast of the mouth of the Pines and Saugus rivers. The sediment is muddy sand. This station has the lowest diversity of all locations examined. The community is dominated by Capitella which together with P. ligni comprise 88 percent of the community.

### 3.6.3.4 Station 4

Station 4 lies south of Station 3 and due east of the Point of Pines. The coarse sand and gravel are indicative of fast moving water. The diversity is high, 3.0, and this station has more species than any of the other stations. The fauna are dominated by Aricidea jeffreysii, a paraonid polycheate. A. jeffreysii is not a species commonly associated with polluted sediments. It is found on bottoms of fine sand/mud (Pettibone, 1963). Capitella sp. is the sub-dominant species. A. jeffreysii and Capitella sp. together make up 57 percent of the total sample abundance.

### 3.6.3.5 Station 5

In the approximate middle of the Harbor, Station 5 lies in 1 foot of water mean low tide (MLT). Twenty-seven species are found here in the coarse sand and silt. These are dominated by Scolecolepides viridis and Capitella sp. which make up 75 percent of the community. Scolecolepides is commonly found in New England estuaries.

### 3.6.3.6 Station 6

Station 6 is the southernmost of the stations located in 1 foot of water MLT. It is dominated by Aricidea jeffreysii and the bivalve mollusk Tellina agilis. Tellina is generally found in muddy sand in shallow water. The two dominant species make up 60 percent of the community abundance. Eel grass was found at this station. The sediment was mud and coarse sand.

### 3.6.3.7 Station 7

Station 7 is located near the center of the Harbor. The sediment is black mud and Ulva sp. was found in several of the grabs. Capitella sp. dominated the community and, along with the bivalve mollusk Pandora gouldiana made up 79 percent of the community. The community had a low index of diversity ($H = 2.1$) and species were unevenly distributed ($J = 0.4$).

### 3.6.3.8 Station 8

The highest diversity ($H = 3.5$) was found at Station 8, located to the east of the Harbor near the dredged channel. The sediment here was composed of sand and silt. Tharyx acutus and Spiophanes bombyx were the community dominants and together made up 49 percent of the assemblage.

## 3.7 Cluster Analysis

Cluster analysis is a multivariate statistical technique by which groups of objects may be classified according to their similarity. The end result of the analysis is a dendogram (or branching tree diagram) in which similar objects are grouped together. The degree or similarity is calculated using a similar coefficient. In this work the Canberra metric coefficient was used. Because of the nature of benthic data, the data were log-transformed before the calculations were performed.

| | | |
|---|---|---|
| Log transformation | = | $\log_{10}(x + 1)$ |
| Canberra metric similarity | = | 1-(1/m) x (Xij - Xik)/(Xij + Xik) |

where:

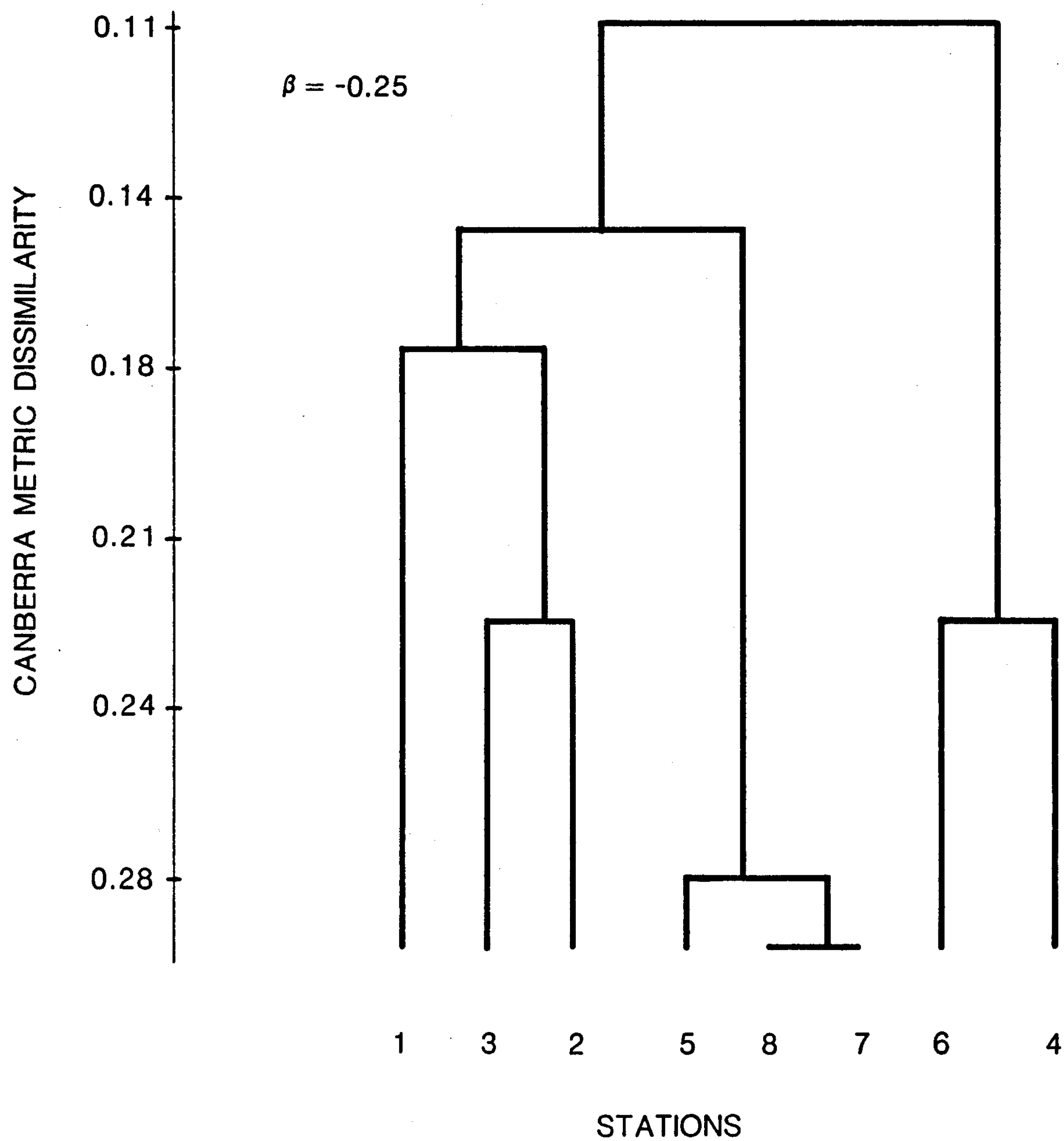
| | | |
|---|---|---|
| m | = | the number of species in the total collection |
| Xij | = | the number of organisms of the $i^{th}$ species at the $j^{th}$ station |
| Xik | = | the number of organisms of the $i^{th}$ species at the $k^{th}$ station |
| X | = | number to be log-transformed |

A flexible clustering strategy was used with $\beta = -.25$. The technique is thoroughly explained by D. Boesch (1977). The analysis was run using a computer program provided by Dr. L. Watling from a modified version of Dr. Boesch's program. The results are shown in Figures 13 and 14.

The most similar stations were 5, 7, and 8. These stations are located in the east to west natural channel. Stations 6 and 4 are located in more oceanic water toward the mouth of the Harbor. Stations 2 and 3, both dominated by Capitella and with muddy sediment, are located in the northwest corner of the Harbor. They are both examples of the Capitella/Polydora ligni association which is commonly found in the estuarine embayments of northern New England. Station 1 was a typical Mytilus edulis community and clustered separately from all other stations.

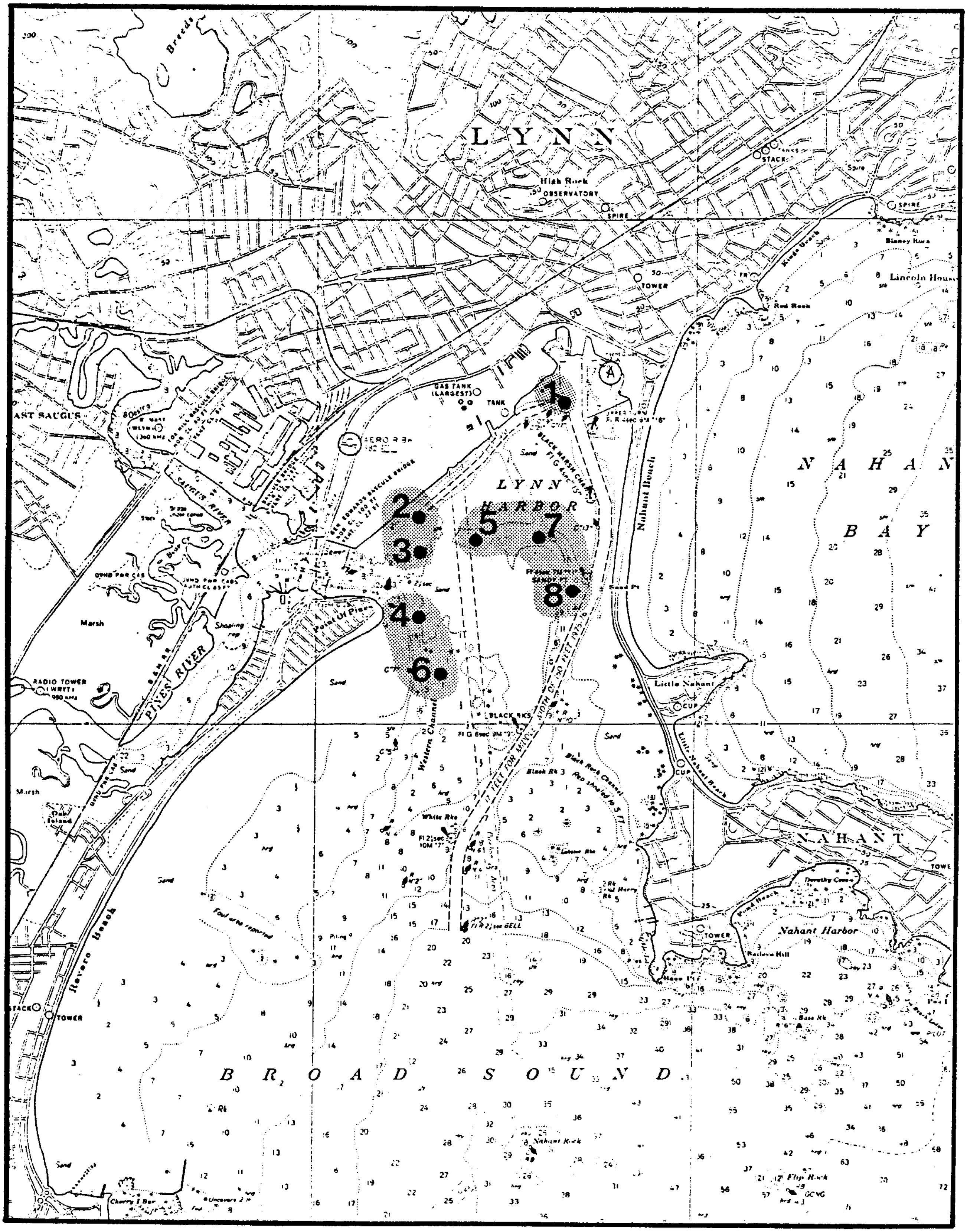
Addtional studies in the area by Raytheon (Raytheon 1972, 1973) provided the following results. Dominant fouling species were Mytilus edulis, Balanus spp., Corophium sp., Hiatella arctica and Phyllodoce groenlandica. Macroinvertebrates captured coincidentally in otter trawls included Crangon septemspinosa, Asterias vulgaris and Littorina littorea. The three subtidal stations which were quantitatively sampled (Raytheon, 1973) are presented in Appendix A. Station 1 was dominated by Nephtys caeca and Mytilus edulis and is described below (Raytheon, 1972a).

LYNN HARBOR: CLUSTER ANALYSIS OF BENTHIC DATA




Source: JASON M. CORTELL and ASSOCIATES INC.

FIGURE 13




C.O.E. SMALL NAVIGATION PROJECT Benthic Cluster Analysis Results
Lynn Harbor, Massachusetts

● Benthic Sampling Stations

0' 1000' 2000'

Source: JASON M. CORTELL and ASSOCIATES INC.

FIGURE 14

3.7.1 Station 1: Existing Plant Site

Station 1, located directly in front of the proposed power plant area, was in 15 to 18 ft (MLW) of water. Bottom sediment was composed of anaerobic black mud with its associated hydrogen sulfide smell. Oil was sometimes mixed with mud. Eelgrass (Zostera), various seeds, cigarette filters, matches, aluminum foil and wads of paper were generally found in the samples. Occasionally the grabs would capture a piece of floating sea lettuce (Ulva) which contained many attached organisms not normally found at this station. Dominant species found were:

| Scientific Name | Common Name |
|---|---|
| Notomastus latericius | Bloodworm |
| Macoma tenta | Clam |
| Lyonsia hyalina | Clam |
| Nephtys caeca | Worm |

Station 2 was dominated by Gemma gemma, Mya arenaria, Tellina agilis and Cyathura polita (Raytheon, 1973), and was described in Raytheon (1972a) as follows:

3.7.2 Station 2: Mouth of Saugus River

Station 2 was located in 12 to 14 ft (MLW) of water at the fork of the Pines and Saugus Rivers. Bottom sediment at this station was composed of coarse sand mixed with larger pebbles and broken shells. Sometime after the week of August 23, 1971, and prior to the week of September 27, a dredging operation was begun on the Pines River (personal observation) and the resulting silt was deposited on the station area. Sediment in the grab sample during the week of September 27 was fine, loosely packed, dark gray silt. No animals were collected at this time. Grab samples during the following month, when dredging had ended, showed that recolonization of the area had taken place and that the silting problem had no continuing effect on the biology of the area. This fine silt, however, did not wash away and remained as the primary sediment type through December.

Dominant species found at Station 2 were:

| Scientific Name | Common Name |
|---|---|
| Nephtys caeca | Worm |
| Macoma sp. | Clam |
| Gemma gemma | Clam |
| Edotea montosa | Isopod |

Station 3, at the Lynn sewage discharge, was characterized by Nephtys caeca, Edotea montosa, and Diastylis polita (Raytheon, 1973) and was described in Raytheon (1972a) as follows:

### 3.7.3 Station 3: Sewage Outfall

Station 3, located adjacent to a sewage outfall in Lynn Harbor between Nahant and Revere, Massachusetts was in 30 ft (MLW) of water. The bottom was composed of sand, oil, stones, toilet paper, cigarette filters, seeds, rubber bands, feces, tar balls, and a variety of food in various stages of decomposition. From the size and kinds of particles noted, this effluent receives little or no treatment prior to discharge.

Oil was first noticed in the sewage outfall area during the July sampling period. The impact of such an addition was undetermined because of stresses produced by existing pollutants.

Dominant species found at Station 3 were:

| Scientific Name | Common Name |
|---|---|
| *Diastylis polita* | Cumacean |
| *Edotea montosa* | Isopod |
| *Nephtys caeca* | Worm |
| *Macoma calcarea* | Clam |
| *Ensis directus* | Razor clam |

## 3.8 Finfish

Shorezone fish of Lynn Harbor are typical of northeast estuaries; dominant species were Atlantic silversides, mummichogs, banded killifish, sticklebacks, and occasional tomcod (Chesmore *et al.*, 1972; Raytheon, 1971, 1972a, 1973). Shorezone fishes were more abundant in the Saugus and Pines River areas than in the Harbor proper.

Winter flounder were abundant in trawls taken in the Pines and Saugus Rivers and near Point of Pines, and were the dominant finfish species. Other species characteristic of the Harbor were yellowtail, tomcod, ocean pout, longhorn sculpin, white hake and little skate (Chesmore *et al.*, 1972; Raytheon, 1971, 1972a, 1973).

Data indicate that the Pines and Saugus Rivers are important winter flounder nursery areas, and that they support modest rainbow smelt and river herring runs. Lynn Harbor supports a recreational fishery for adult winter flounder year-round, and a seasonal fishery for cod, mackerel, pollock, and bluefish.

## 3.9 Shorebirds and Waterfowl

Shorebird data for Lynn Harbor are limited and indicate heavy usage of the Point of Pines and central mussel shoal areas by dunlin (120) and sanderling (90) (TASL, 1980). Spring, summer and fall usage by these and other species is undoubtedly greater than this single winter observation.

Many waterfowl overwinter in Lynn Harbor or migrate through in spring and fall. Data from 1979-1980 (H. Houseman, 1980, unpublished data) indicate heavy usage by scaup (25,529 sitings), eider (21,508), black ducks (6,560), bufflehead (1,412), goldeneye (761) and red-breasted merganser (286). Other species observed were brant, common merganser, horned grebe, mallard, harlequin, cormorant, hooded merganser, and loons. Most species made heaviest use of the Nahant causeway shore from Little Nahant south, although scaup and eider often rafted in the south-central Harbor; fish-eating species (mergansers, cormorants) aggregated near the rivermouth; and brant and black ducks also used the Revere Beach-Point of Pines area. Bird observations by "Take a Second Look" confirm Houseman's data (Soheil Zendeh, personal communication) (Normandeau, 1980). None of these species are either State or Federally-listed as threatened or endangered.

## 3.10 Marine Mammals

Lynn Harbor is utilized as a winter feeding/resting area by Harbor seals.

## 3.11 Threatened and Endangered Species

No species which occur in Lynn Harbor are threatened or endangered at this time. Three species which are endangered might stray into the Harbor in the course of migratory behavior. These are:

1. Peregrine falcon: known to overwinter in Boston on large public buildings, feeding on rock doves.

2. Bald eagle: has been observed in migration.

3. Short-nosed sturgeon: last recorded at Provincetown, Massachusetts in 1907.

Lynn Harbor and its tributaries do not provide critical or even suitable habitat for any of these species. Endangered large whales and sea turtles may occur off Nahant, but would not be expected to utilize Lynn Harbor (Douglas Beach, NMFS: Personal Communication, Richard Dyer, USFWS) (Normandeau, 1980).

## 3.12 Historical and Archaeological Resources

Improvement dredging within all the project alternatives now under consideration appears unlikely to affect significant historical or archaeological resources. The project area consists of mudflats which have been frequently modified by currents from the mouth of the Saugus River and within Lynn Harbor. Therefore, undisturbed prehistoric resources are highly unlikely.

Numerous historic period shipwrecks are reported in the open sea off the east shore of Nahant, but Lynn Harbor provides a more sheltered area where no wrecks are recorded, and unrecorded wrecks appear unlikely. Historic marine activity in Lynn was confined to the present turning basin and an area up the Saugus River. No wharves are recorded adjacent to the proposed channel and turning basin areas.

# 4.0 ENVIRONMENTAL CONSEQUENCES

The purpose of this section is to present the expected positive and negative effects of the various alternatives. In each case, anticipated direct, indirect, and cumulative effects are assessed. Impact components include physical, chemical, and biological parameters.

## 4.1 Direct Effects and their Significance

### 4.1.1 Effects in Lynn Harbor

Direct effects on the physical, chemical, and biological environment resulting from dredging activity and breakwater construction are treated below. Because alternatives differ only in the quantity of proposed dredging and in the presence or absence of a breakwater, the impacts may be evaluated in a generic manner. The magnitude of the impact is proportional to the quantity of dredging.

### 4.1.2 Physical Effects in the Harbor

Effects of Dredging

Two types of dredging techniques are generally used in the New England area: hydraulic and bucket dredging. Because of the lack of suitable upland disposal sites, it is unlikely that hydraulic dredging will be used. Hydraulic dredging requires nearby land disposal sites of sufficient capacity to allow both holding and dewatering of the dredged material. Sites of this capacity are not locally available. The preferred dredging method is the use of a barge mounted clamshell dredge. With appropriate bottom sediment types, this dredging method allows the removal of large, cohesive masses of bottom sediment. Thus, turbidity levels are minimized at both the dredge site and disposal site.

Towed or motorized disposal barges are the preferred transport system for dredged material disposal. Split hull disposal barges reduce the number of trips and time required for completion of dredging. From an environmental standpoint, these two methods are indistinguishable in terms of potential impacts.

The intertidal fauna at the dredging site will be replaced by subtidal fauna. Presently, the intertidal mussel flats serve as a resource for a number of waterfowl which migrate through the area. The extent of the removal of these flats will be proportional to the quantity of dredging which takes place.

During dredging there will be an increase in turbidity. This is likely to cause fish to move away from the area temporarily and may affect shellfish beds in the area. The potential impacts on water quality, in addition to the increased turbidity, include increases in BOD, nutrients, heavy metal concentrations, and odor in the area of the sediment plume. The environmental impacts to the Harbor will be directly proportional to the extent of the dredging which takes place.

The primary physical effect of dredging in the Harbor will be an increase in suspended solid concentrations due to bucket loss during each movement of the dredging bucket. According to Bohlen (1978), these losses range from 1.5 to 4.0 percent of each bucket load.

Work in the Thames River, Connecticut, has shown that dredge-induced resuspension of sediments is "primarily a near field phenomenon and represents a relatively small scale disturbance of the suspended material field within the estuary." (Bohlen, 1978). Any increase in total suspended sediment concentration will be noticeable over a relatively small area.

Wave studies have shown that there is little need for a breakwater since wave heights in the Harbor, even with hurricane force winds, will be less than 2.5 ft. A storm which occurred on the 25th of October, 1980, allowed field confirmation of these predictions. Waves were observed to be less than 2.5 ft and would not pose a threat to a properly moored vessel. However, the vertical seawall which presently exists at the site of the proposed breakwater, does, by reflecting wave energy, create "chop" which may pose such a threat. The reflective nature of this seawall may be alleviated by the placement of rip-rap or substitution of a sloping seawall to absorb, rather than reflect, the wave energy.

The dredging will modify the bottom over an area whose dimensions and location vary with the alternatives. Thus, the alternative with the most dredging will have the greatest impact.

Breakwater construction will affect current patterns in the Harbor. Results of computer modeling have shown that erosion is likely to take place at Point of Pines if a non-permeable breakwater is constructed. A detached breakwater would not be likely to have this erosive impact. The detached breakwater model (JMCA, 1980) caused minimum alteration of existing flow patterns. The tide range, and therefore the tidal prism inside the proposed breakwater, will not be altered in either case. The present exchange of water inside the breakwater site is approximately 80 percent with each tide cycle. If a basin is dredged to -25 ft MLW, exchange of water will not be less than 30 percent. This may be increased by flood tidal currents flowing through the enclosure, especially in the case of a detached breakwater (JMCA, 1980).

### 4.1.3 Biological Effects in the Harbor

The major effect of dredging is the removal of habitat and organisms from the Harbor bottom. Concomitant with this is the spreading of a turbidity plume and the presentation of a large surface area of sediment to the water column. This large surface area allows chemical exchange to take place between the sediment and the water column. Stern and Stickle (1978) point out that turbidity "may reduce photosynthetic activity by interference with light penetration." Laboratory studies on the effects of turbidity indicate that increasing concentrations of suspended sediments produce abnormal development of bivalve eggs and larvae. Adult bivalves seem to cope well with increased turbidity, and adult fish are more sensitive to turbidity than most invertebrates. Stern and Stickle (1978) conclude however, "The literature indicates that turbidity and suspended solids conditions typically created by most dredging operations are of short duration and unlikely to produce severe and irreversible ecological effects." An additional review of the effects of suspended sediment on marine and estuarine organisms is provided in JMCA, 1980b.

The possibility exists that the cysts of the red tide organism, Gonyaulax tamarensis may be exposed by dredging, and that the exposure of these cysts, combined with increased nutrient levels, could cause a red tide bloom (Dale et al., 1978; Anderson and Wall, 1978; Anderson and Morel, 1979). Although G. tamarensis has not been identified in Harbor samples, Massachusetts North Shore shellfishing has periodically been closed due to blooms of this paralytic shellfish poisoning agent (Raytheon, 1979).

Feng (1975) found that the effect of dredging was to increase phytoplankton productivity. He attributed this increased production to elevation of nutrient concentration due to the release of nutrients from sediments exposed to the water column.

Without doubt, the removal of organisms and bottom sediment will have an effect on the environment; but the magnitude of this effect is dependent to a great degree on the stability of the benthic communities present. Community stability can be defined in two ways: the first is in terms of resiliency, and the second in terms of constancy (Holling, 1975). A community that is stable in terms of constancy maintains its structure despite small environmental perturbation. However, if such a community is subject to such a large perturbations that its structure is altered, it will take a long time to recover. A resilient community, on the other hand, is easily disturbed by perturbations but has a very fast recovery time. The resilient community is characterized by short lived species with high reproductive potential and thus, is less likely to be adversely affected by dredging.

In areas of previous dredging, the resilience of the community (indicated by the species present and low diversity) suggests that complete recolonization will take place within six months to a year. It is likely that opportunistic polychaetes such as Capitella sp. and Polydora ligni will be among the first macrobenthic organisms to appear in the defaunated river bottom. McCauley et al. (1974) found that diversity returned to prior levels within seven days of dredging.

In the areas presently covered by intertidal mussel beds, the result of the dredging will be to substitute subtidal fauna for the intertidal flats which presently serve as a resource for wild fowl.

No reports of endangered or protected species are available for Lynn Harbor.

Mitigation Measures

Current speeds within the Harbor are sufficiently low that silt curtains or turibidity barriers will effectively reduce turbidity, measured in NTU, to within 50 NTU of ambient levels (Johansen, 1978).

### 4.1.4 Chemical Effects in the Harbor

The most immediate area of concern posed by dredging and dredged material disposal is the increased availability of metals and other constituents that may have a deleterious impact on water quality, and hence, on marine biology. The assessment of potential impacts to the physical and chemical environment attributable to the dredging and disposal of Harbor sediments was limited by the availability of data from the area.

Bioassays conducted by the ERCO on sediment from the -22 ft dredged channel (ERCO, 1979) showed the sediments and their interstitial waters to be non-toxic to copepods, shrimps, and Atlantic silversides. Tables 4 and 13 show the levels of metals from bottom sediments of Lynn Harbor. According to the Massachusetts Disposal Criteria (Massachusetts Division of Water Pollution Control, Regulations for Dredging, Dredged Material Disposal, and Filling in Waters of the Commonwealth, August 28, 1978), the sediments from Lynn Harbor are classified as Category Two materials because mercury concentrations exceed 0.5 ppm. Oil and grease content place the materials in Category Type B.

### 4.1.5 Effects at Disposal Sites

It is probable that dredged materials will be disposed at the EPA-approved Boston Foul Area. Effects of dredged material disposal in the marine environment are two fold. Both are short term effects. The first is the effect of the exposure of sediment surface to the water column while the sediment drops through the water column and the second is the smothering of the existing bottom community.

Immediately following a disposal operation, dissolved oxygen and pH levels are expected to be depressed within the turbidity plume itself. Also, within the plume, the concentration of suspended solids, volatile solids, and organic carbon are expected to increase as a direct result of sediment disposal.

The benthos beneath the disposal point will be smothered by the rapid influx of new material: The results of the smothering will be dependent upon the resiliency of the community and the ability of independent organisms to burrow their way to the surface. The addition of sediment of a type different than the existing sediment may result in a permanently altered final community. Rhoads (1978) has shown that managed disposal can enhance the productivity of a disposal site.

Results of bioassay studies by ERCO (1979) and by New England Aquarium (1979) demonstrated that the material from Lynn Harbor is suitable for disposal at Boston Foul Area. Bioaccumulation studies performed by ERCO (1980) on Lynn Harbor sediments for the Corps of Engineers, showed no elevation in cadmium, mercury, PCBs, petroleum, hydrocarbons, and the DDT concentrations in exposed organisms compared to organisms exposed to the foul area sediments.

In order to determine the suitability of this material for fill at Massport, further bulk and elutriate testing would be required. Details of the impact of disposal at Massport are presented in JMCA, 1980.

Since sand grain sizes on Revere Beach range from 0.2mm to small cobble (P. Rosen, Personal Communication), it is unlikely that any of the finer material from Lynn Harbor would remain onsite for any period of time. Thus, this material will not be suitable for beach replenishment.

### 4.1.6 Use of a Breakwater and Pier

Another alternative, not previously examined, is to provide a breakwater which allows circulation patterns in the Harbor to remain relatively undisturbed. This alternative provides the advantage of reducing shop without the disadvantages incurred by a continuous breakwater.

By constructing a pier across the western channel as a Land-Breakwater connection, the needs of the City of Lynn could be adequately served without undue erosion impact to the Point of Pines and without impacting the water quality of the basin.

## 5.0 PUBLIC INVOLVEMENT AND COORDINATION

A number of public meetings have been planned to ensure that local interests remain informed upon the status of this project. Additionally, the following individuals were contacted during the development of this study.

Mr. Dudley Baker
NEW ENGLAND RIVER BASINS COMMISSION
Boston, MA

Mr. Douglas Beach
NATIONAL MARINE FISHERIES SERVICE
NOAA
U.S. Department of Commerce
P.O. Box 1109
Gloucester, MA 01930

Ms. Susan Brownell
UNIVERSITY OF RHODE ISLAND
Marine Program Office
Regional Coastal Information Center
Narrangansett, RI 02882

Ms. Anne Caplin, Executive Director
NEW HAMPSHIRE OCEANOGRAPHIC FOUNDATION
Office of Cooperative Ocean Programs
45 Pleasant Street
Portsmouth, NH 03301

Ms. Sara Caroll
MASSACHUSETTS COASTAL ZONE MANAGEMENT
100 Cambridge Street
Boston, MA 02202

Dr. John J. Cochrane
Department of Civil Engineering
NORTHEASTERN UNIVERSITY
360 Huntington Avenue
Boston, MA 02115

Mr. Peter DeVeau, Planner
Planning Department
CITY OF LYNN
Lynn, MA

Ms. Candace Dunn
UNIVERSITY OF RHODE ISLAND
Marine Program Office
Regional Coastal Information Center
Narrangansett, RI 02882

Richard Dyer
U.S. FISH & WILDLIFE SERVICE
Newton Corner, MA

Ms. Betty Edel
National Sea Grant Depository
Pell Library, Bay Campus
UNIVERSITY OF RHODE ISLAND
Narragansett, RI 02882

Mr. Richard Forster
MASSACHUSETTS AUDUBON SOCIETY
Lincoln, MA

Mr. Kevin Geaney, City Planner
Planning Department
CITY OF LYNN
Lynn, MA

Dr. Peter Greenwood
Department of Resource Economics
Institute of Natural and Environmental Resources
UNIVERSITY OF NEW HAMPSHIRE
Durham, NH 03824

Dr. Constantine J. Gregory
Department of Environmental Science
NORTHEASTERN UNIVERSITY
Boston, MA 02115

Mr. Jack Hannon
Division of Waterways
MASSACHUSETTS DEPARTMENT OF ENVIRONMENTAL
QUALITY ENGINEERING
100 Nashua Street
Boston, MA

Dr. Andreas Holmsen
Department of Resource Economics
UNIVERSITY OF RHODE ISLAND
Kingston, RI 02881

Mr. James H. Houseman, Waterfowl Biologist
Division of Fisheries and Wildlife
MASSACHUSETTS DEPARTMENT OF FISHERIES, WILDLIFE
AND RECREATIONAL VEHICLES
Westboro, MA

Ms. Debby Howard
MASSACHUSETTS AUDUBON SOCIETY
5 Joy Street
Boston, MA

Mr. Rusty Iwanowicz
Division of Marine Fisheries
MASSACHUSETTS DEPARTMENT OF FISHERIES, WILDLIFE AND
RECREATIONAL VEHICLES
Cat Cove Marine Laboratory
92 Fort Avenue
Salem, MA 01970

Ms. Esther Johnson
MASSACHUSETTS HISTORICAL COMMISSION
40 Beacon Street
Boston, MA

Ms. Carol Kilbride
Division of Marine Fisheries
MASSACHUSETTS DEPARTMENT OF FISHERIES, WILDLIFE AND
RECREATIONAL VEHICLES
100 Cambridge Street
Boston, MA 02202

Mr. Douglas Marshall, Executive Director
NEW ENGLAND FISHERIES MANAGEMENT COUNCIL
Peabody, MA

Mr. Edward McDonald
Division of Waterways
MASSACHUSETTS DEPARTMENT OF ENVIRONMENTAL
QUALITY ENGINEERING
100 Nashua Street
Boston, MA

Ms. Carol Price
UNIVERSITY OF RHODE ISLAND
Kingston, RI 02881

Mr. Warren Rathjen
NATIONAL MARINE FISHERIES SERVICE
NOAA
U.S. Department of Commerce
P.O. Box 1109
Gloucester, MA 01930

Mr. Edward Reiner
Permits Branch
U.S. ENVIRONMENTAL PROTECTION AGENCY
Region I
Boston, MA

Mr. Edwin Robinson
U.S. FISH AND WILDLIFE SERVICE
Department of the Interior
Ecological Services
P.O. Box 1518
Concord, NH 03301

Mr. Robert Temple, Chief
Fisheries Development Division
NATIONAL MARINE FISHERIES SERVICE
NOAA
U.S. Department of Commerce
P.O. Box 1109
Gloucester, MA 01930

Ms. Debby Truitt
NEW ENGLAND MARINE ADVISORY SERVICE
New England Center
Durham, NH 03824

Mr. Sterling Wall
Division of Wetlands
DEPARTMENT OF ENVIRONMENTAL QUALITY ENGINEERS

Mr. Soheil Zendeh
380 Broadway Street
Somerville, MA 02145

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